



CALIFORNIA ENERGY COMMISSION

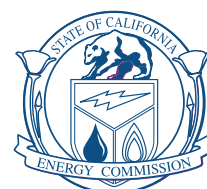
PUBLIC INTEREST ENERGY RESEARCH

2003 ANNUAL REPORT

Appendix 3
Renewable Energy Technologies



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Arnold Schwarzenegger,
Governor

Renewable Energy Technologies

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REN Multi-Year Projects Started in 2003

Community Choice Aggregation Pilot Project

Contract #: 500-03-004

Contractor: Local Government Commission (LGC)

Contract Amount: \$694,000

Contractor Project Manager: Patrick Stoner (916) 448-1198

Commission Contract Manager: Hassan Mohammed (916) 651-9855

Status: Active

Project Description:

The purpose of this contract is to develop a template that local governments can use in evaluating the feasibility of implementing Community Choice Aggregation (CCA) within the context of the California Renewables Portfolio Standard (RPS). The template will be developed based on assessments conducted with a minimum of three pilot communities. The template will address the technical and economic aspects of incorporating renewables under a community aggregation vehicle, and lessons learned by pilot communities. In addition to the developed template, a report will be prepared on the procedures established by the California Public Utilities Commission (CPUC) in implementing CCA. Both the template and the report on the CPUC's implementation process will be disseminated to interested communities through workshops and publications.

Passage of recent legislation has created significant changes in California's electricity markets. AB 117 (2001-02) (Migden) and SB 1078 (2001-02) (Sher) provides local governments with the ability to aggregate electricity loads within their communities and act on behalf of those customers in selling and purchasing electricity, transmission and other services. The RPS requires retail sellers of electricity, including electric service providers, electrical corporations and community choice aggregators to increase their purchase of electricity from renewable sources to twenty percent by 2017. Due to the rich supplies of indigenous renewable resources in California and adjacent states, retail electricity sellers will look increasingly at regional supplies of renewables to help achieve the RPS goals. Similarly, some communities in California have interest in developing a renewable portfolio mix that significantly exceeds the state's RPS twenty-percent goal.

This project supports the PIER Program objectives of:

- Providing greater choices for California consumers.
- Expanding the use of renewable energy technologies in California's electricity mix.

Proposed Outcomes:

1. Develop a template of analytical and cost models that can be used by a variety of local governments in California in assessing ways to implement CCA in such a fashion to significantly exceed the state's RPS goals.
2. Prepare a document that clarifies the costs, credits, rules and protocols being established by the CPUC for implementing CCA.
3. Develop a CCA Pre-feasibility Study Model.
4. Complete detailed CCA feasibility analyses for up to three communities or groups of communities that demonstrate the use of the template and ways in which these communities can significantly exceed the state's twenty- percent RPS goal.
5. Develop and provide a guidebook, fact sheet, and workshops for local government elected leaders and staff that share the lessons learned with the pilot communities.

Project Status:

Kickoff meeting was held on September 16, 2003. Project is on-going.

Photovoltaic Power Generation with Direct Current Applications

Contract #: 500-02-014 Work Authorization #: E2I-WA-106

Contractor: Electricity Innovation Institute

Project Amount: \$24,800

Contractor Project Manager: Terry Peterson

Commission Contract Manager: George Simons (916) 654-4659

Status: Active

Project Description:

Traditional use of photovoltaic (PV) power in grid-connected applications involves the use of solid-state power-electronic devices called inverters to convert the PV modules' dc output to ac power. These inverters unavoidably add to system cost and lower system efficiency. Furthermore, to date, they have proven to be the least reliable and durable component of grid-connected PV installations.

This project is intended to significantly advance the economics of photovoltaic (PV) energy by investigating approaches for applying PV in non-traditional dc-power applications without inverters. Unlike conventional dc uses for PV energy, such as off-grid telecommunication sites, navigation beacons, and billboard lighting, this project will develop the hardware and demonstrate the powering of loads at grid-connected buildings in cases where the PV can provide supplemental dc power without interference to the ac distribution system or load. Potential examples include adjustable-speed motor drives, building lighting systems, appliances with switch-mode power supplies, heating systems, and uninterruptible power supplies. This project includes a feasibility study, hardware development and a completed demonstration with performance results.

Goals of the Work Authorization:

The goal of this Work Authorization is to significantly advance the economics of PV energy by investigating approaches for applying PV in non-traditional dc-power applications.

This project supports the PIER Program objectives of:

This Work Authorization meets the PIER Goal of Improving the Environmental and Public Health Costs/Risk of California's Electricity by enabling more cost-effective—and therefore, wider—use of PV electricity in grid-connected applications. To the extent that dc-PV applications displace more conventional grid-connected PV deployments, this Work Authorization also meets the PIER Goal of Improving the Energy Cost/Value of California's Electricity, because it will improve the economics of PV utilization.

Proposed Outcomes:

The objectives of this Work Authorization are to demonstrate the feasibility of at least one novel dc-PV application and quantify its economic advantages compared to traditional ac-connected configurations.

Project Status:

This project is active.

Wind Energy Resource Modeling and Measurement

Contract #: 500-03-006

Contractor: TrueWind Solutions, LLC

Contract Amount: \$424,500

Contractor Project Manager: Bruce Bailey (978) 749-9591

Commission Contract Manager: Michael Kane (916) 654-7119

Status: Active

Project Description:

In a previous project for the California Energy Commission (Commission) entitled “New Wind Energy Resource Maps of California,” Contract #500-01-009, TrueWind Solutions used its advanced MesoMap system to produce highly detailed maps and data files of the state’s wind energy resources. The underlying purpose of the project was to encourage the development of wind energy in the state by helping companies and individuals identify promising wind project sites with a minimum of effort. The maps were validated using wind measurements from 266 locations throughout the state, including airports, ocean buoys, and towers instrumented specifically for wind resource assessment. This validation process determined that the mean wind speed estimates were accurate to within a standard error of about 0.4-0.6 m/s, or 6-8%, at a height of 50 m above ground.

Although the new maps and data files represent a major advance over the previous understanding of the states wind resources, there is room for improvement. A standard error of 6-8% in mean speed implies an uncertainty margin, with 95% confidence, of roughly 20-30% in wind turbine output. In the final report of that project, TrueWind Solutions identified several issues affecting the accuracy of the wind resource estimates and presented the following recommendations for further research:

1. High-resolution modeling of selected areas. Certain aspects of California’s unusually complex wind regime, such as blocking by coastal mountains and channeling through narrow passes, could not be modeled very accurately at the 2 km grid scale of the MASS simulations. As tests carried out by TrueWind Solutions have shown, higher resolution MASS runs could improve the accuracy of the wind resource estimates in promising areas.
2. Analysis of boundary layer issues. The stability of the nighttime boundary layer has a major impact on the wind resource in certain parts of California, particularly the desert, where it may insulate the surface from high winds aloft. However, it poses a significant modeling challenge that could not be fully explored in the previous project. In-depth research on methods of simulating stable atmospheric conditions could substantially improve the accuracy of the wind maps in such areas.
3. Measuring the wind aloft. Most of the towers that provided data for the validation of the maps were less than 20 m tall, and lack of knowledge of the wind shear above that height consequently introduced a large uncertainty in the wind resource that would be experienced by modern wind turbines. New measurements using taller towers in promising areas are clearly needed. However, even the current standard 50 m towers do not reach the hub height of modern turbines, which is typically 70 to 80 m, let alone the tops of their blades, which may reach 130 m above ground and taller towers are expensive. Existing communication towers, however, can offer a relatively inexpensive platform from which to take direct wind measurements at relevant heights in the vicinity of 100 m above ground. New techniques such as sonic detection and ranging (sodar) can measure the wind to heights of 200 m or more at a moderate cost. In addition to exploring

the wind resource at a particular site, sodar could be useful in validating and refining models to simulate the boundary layer, with benefits in other areas being mapped.

The overall goal of this project is to improve the accuracy of wind resource estimates in promising areas of the state by addressing the three issues outlined above. This is to be a comprehensive, integrated program of measurement and modeling. Five promising areas of the state will be selected. Two of these will be in major, known wind resource areas such as Tehachapi or Altamont Pass where an abundance of data is already available. The others will be in relatively unexplored areas (with a variety of types of terrain) showing promise for wind energy development. The measurement program will include very tall towers (with co-funding to the Commission provided by the US Department of Energy's State Energy Program) as well as sodar. The modeling will involve running MASS at high resolution to improve the simulation of mountain blocking and channeling, as well as downslope flows, while using data from tall towers and sodar to validate and improve the boundary layer formulations.

This project supports the PIER Program objectives of:

This project meets the PIER Goal of improving the reliability and quality of California's electricity by more accurately defining wind resources in the state and identifying areas of untapped wind potential. This project also helps to improve energy cost/value of California's electricity by providing better understanding of wind resources and helping to increase market penetration levels through coupling numerical modeling capabilities with met tower monitoring.

Proposed Outcomes:

The objectives of this project are: 1) to generate high-resolution wind resource maps targeting areas of complex terrain and meteorology, and 2) to provide measured wind data and winds aloft data that will be publicly accessible. The high-resolution wind mapping project was initially designed to encourage the development of wind energy in the state by helping companies and individuals identify promising wind project sites with a minimum of effort. By coupling computational capability with site measured data for validation, the new state maps provide a valuable resource in the absence of historical met tower data. With successful completion of this project, the state will possess one of the highest resolution maps at 200m with regional refinements at the 100m level. These refinements are expected to increase the overall accuracy of the maps by 50%. The state will have contributed to improving the accuracy and refinement of a state-of-the-art technology for providing wind mapping and forecasting services to industry. This project is expected to increase wind market penetration by small and large wind technologies. The project will provide the first wind data using sodar technology for the state and will extend our understanding of upper wind characteristics from typical 50m to 200m.

Project Status:

The project was started in September, 2003. Efforts to date focus on identifying existing towers for wind measurement and securing use agreements from tower owners. Work also progresses on the selection of focus areas for high-resolution modeling and analysis. Field measurement is expected to commence in the March-April time frame.

REN Active Projects from Previous Years

Biogas/PV Micro-Grid Renewable Resource Program

Contract #: 500-00-036

Contractor: Commonwealth Energy Corporation

Subcontractors: Regional Economics Engineering, Inc. : Endecon Engineering : Renewable Energy Development Institute : Zaininger Engineering Company : SDV/ACCI : CH2M Hill, Inc.

Contract Amount: \$11,668,572

Match Amount: \$11,719,500

Contractor Project Manager: Patrick Lilly (360) 906-0616

Commission Contract Manager: Zhiqin Zhang (916) 654-4063

Status: Active

Program Progress:

Currently all seven of the PIER Commonwealth Projects are active and moving forward within their original approved scope of work. There have been no significant changes in Program work scope as required to date.

Program Schedule:

Although several of these projects have experienced notable delays --due to unanticipated amount of time required to acquire and compile the project planning and analysis information, most projects are proceeding along schedule. Although some of these delays in scheduled tasks may impact overall Project completion dates, a revised Contract Exhibit B was developed and this action addressed the requested schedule changes for each of these projects.

Program Budget:

A total of \$703,218 or 6% of total PIER Program funds were actually invoiced by Commonwealth to the Commission. Additional PIER and match fund resources have been expended to date on deliverables that are in progress – but have not yet been invoiced to the Commission, as they have either not been fully completed or approved by the CEC Program managers. Overall, the program is on target to date with respect to their budgeted funds versus actual expenditures.

Program Issue:

One issue has been raised related to the six biogas and PV projects of the Commonwealth program that are not fully coordinated within an overall Program implementation plan that targets using renewables to address electricity affordability issues in the mini-grid. The Commission asked Commonwealth to submit a business plan to describe how Commonwealth intends to use the results from the projects to make electricity in the Commonwealth service area more affordable and diverse. The draft business plan was prepared and submitted to the Commission as scheduled on January 12, 2004. A meeting was then held on January 16, 2004 at the Commission on the draft business plan. The Commission shall provide Commonwealth written comments to their draft business plan, which will then be finalized and submitted under a confidentiality request to the Commission by Commonwealth Energy.

Biogas-fueled Low Emission HCCI Generator

Contract #: PIR-02-003

Contractor: Makel Engineering Inc./Darby B. Makel

Contract Amount: \$457,042

Match Amount: \$149,995

Contractor Project Manager: Darby Makel (530) 895-2771

Commission Contract Manager: Valentino Tiangco Ph.D. (916) 654-4664

Status: Active

Project Description:

The purpose of this project is to demonstrate the applicability of Low Emission Homogeneous Charge Compression Ignition HCCI engine technology for landfill gas (LFG) fueled power generation at the Butte County Neal Road Solid Waste Management Facility.

The biogas-fueled low emission HCCI engine-generator project provides a low risk path to high efficiency, low emissions and low cost power generation relative to any other technology. This proposed project would install a 100kW system at the Butte County Neal Road landfill facility. HCCI technology is uniquely suited to address the key challenges related to landfill gas power generation such as low energy content, variable ignition characteristics (octane value), and contaminants. These issues present less of a problem to HCCI engines than to conventional engines, gas turbines and fuel cells. Is successfully developed, the technical advancements of this research include:

- Optimizing the power output and emissions of the HCCI lean-burn engine: Demonstrate the efficiency of the engine while maintaining ultra low NO_x emissions and acceptable power density.
- Tuning the Control System to perform on the variable energy density of landfill gas: Demonstrate the stability of the engine considering that engine control is difficult because there is no spark plug (good), no fuel injector (good), and thus, no direct control of the ignition timing (bad).
- Leveraging the Fuel Flexibility of the HCCI Engines to operate on landfill gas: Demonstrate the durability of the engine running on waste gas with potential contaminants and corrosives.

This project supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by providing a low-cost high-efficiency distributed power generation engine that runs on LFG.
- Improving the environmental and public health costs/risk of California's electricity by efficiently using LFG to generate electricity (removing this potent greenhouse gas from the environment) while limiting the engines emissions to very low levels.

Proposed Outcomes:

1. Demonstration of NO_x emission of 0.005 lb/MM Btu and how HCCI engine technology contributes to improving both the environmental and human health conditions through utilizing LFG as a feedstock thus removing it from the atmosphere where it is a potent greenhouse gas.
2. Demonstration of the real world effectiveness of HCCI engine technology utilizing LFG at 35% efficiency (both emissions and power), stability (consistent engine performance

- over time, less than 10% variation on efficiencies) and durability (>10,000 hours between overhauls).
3. Demonstration of the market ready potential of HCCI engine technology as a low cost and high efficiency source of distributed electric power generation.
 4. Reduction of the cost of electricity generation by 50% to <0.05 \$/kWh.
 5. Reduction of the cost of system installation to <750 \$/kW.

Project Status:

The project is ongoing. Kickoff meeting was held on March 14, 2003. The draft design package for the landfill gas fueled HCCI demonstration system has been completed for review by Commission Staff and outside experts. Work is progressing for the testing that will commence in 2004 and the Contractor is within schedule and budget.

California Biomass Collaborative

Contract #: 500-01-016

Contractor: Regents - Davis

Contract Amount: \$415,716

Contractor Project Manager: Bryan M. Jenkins (530) 752-1422

Commission Contract Manager: Valentino Tiangco Ph.D. (916) 654-4664

Status: Active

Project Description:

The purpose this project is to create a forum to address ways to further the beneficial development of biomass energy in California. As the only California-focused effort of this kind, the Collaborative will serve as a unique forum for coordinating biomass energy development in the state among key stakeholders. The Collaborative will also provide the Commission with access to biomass energy expertise that will help in achieving objective and timely evaluation of biomass energy policies, and evaluation and implementation of proposed biomass energy technology innovations.

The mission of the Collaborative is to enhance the development of sustainable and beneficial biomass energy systems for the state of California. To fulfill this mission, the Collaborative plans to administer a comprehensive statewide program addressing research and innovation technology development, demonstration, and deployment and biomass energy education and training. The Collaborative plans to accomplish this mission through the close cooperation of representatives from California's biomass energy and products industries representatives from affected federal and state agencies the environmental community and research and academic institutions involved in biomass energy developments.

This project supports the PIER objectives of:

- Improving the cost/value, environmental and public health costs/risks, reliability/quality, and safety of California's electricity by advancing the state's renewable biomass energy industry.
- Providing more energy choices for California ratepayers and maximizing the market connectivity of biomass technologies developed through the PIER Program.

Proposed Outcomes:

1. Organization and management of a diverse collaborative advisory group (the Collaborative) to provide immediate expertise in areas pertaining to biomass energy including technologies, resources, design, siting, construction, operation and maintenance, generation, and modeling.
2. Organization of an Executive Board to administer the overall function of the Collaborative.
3. Enlistment of staff to carry out the day-to-day and project oriented activities of the Collaborative.
4. Establishment of a physical focal point for biomass energy related questions/activities in the state.
5. Development of topical papers specific to California that evaluate existing biomass resource inventories and the potential for new biomass resource development and markets. In addition, the papers will assess technical, economic, and environmental performance of current and potential future biomass power generation systems that address California electricity needs with respect to reducing congestion and increasing peak generating capacity. These papers will be designed to establish the background for

bioenergy development in the state and to generate recommendations, directions, and priorities for policy, research, demonstration, education, standards, and other activities and projects needed to advance biomass power systems.

6. Support statewide biomass-related GIS modeling efforts and enhance state level biomass inventory data.
7. Creation of a California Biomass Facilities Reporting System to provide up-to-date information on biomass power facilities and facility performance.
8. Development of a Collaborative web site for disseminating and improving public access to biomass information, data, white papers, and Consortium activity reports.

Project Status:

- The organization of the California Biomass Collaborative was formally established on February 5, 2003. Technical staffs were recruited and the Executive Board was formed.
- The website for the California Biomass Collaboration is operational at <http://biomass.ucdavis.edu>.
- The Collaborative has 317 members and continues to attract membership.
- The Executive Board of the California Biomass Collaborative has 16 members and met on August 4, 2003 and January 9, 2004. The Executive Board committees on research, policy, outreach and education have been created to support the tasks and mission of the Collaborative. Policy and Research Committees have drafted reports or future plans for the Collaborative and are addressing critical needs of the industry and State.
- The First Annual Forum of the Collaborative was successfully held on January 8, 2004 with 200 participants in attendance. The agenda and proceedings are on the Collaborative Website at: <http://biomass.ucdavis.edu/pages/forum/forum.html>.
- Work continues on the following technical tasks: updating the California biomass resource assessment, conducting a power generation assessment, instituting a biomass facilities reporting system, and developing web accessible economic models for biomass energy conversion technologies.

California Wind Energy Consortium

Contract #: 500-00-029

Contractor: University of California, Davis

Contract Amount: \$537,882

Contractor Project Manager: Bob Richardson (530) 474-4819

Commission Contract Manager: Dora Yen (916) 653-4128

Status: Active

Project Description:

Based on input from California's wind energy industry, the PIER Program determined a need to establish a forum in which issues critical to further wind energy development in the state could be addressed and coordinated among the key stakeholders. The purpose of this project is to establish a wind energy collaborative that brings together key stakeholders with a specific focus on further beneficial development of California's wind energy resources. As such, the Collaborative will represent the first statewide and California-focused effort at tying together activities on wind energy research and development, commercialization, critical path analysis and education to help resolve key technical, environmental, economic or institutional barriers.

Collaborative members include representatives from the wind energy industry, Energy Commission staff involved in wind energy development, U.S. DOE/NREL staff, members of the environmental community and representatives from the academic and research communities conducting wind energy research. A primary goal of this project is to establish and plan the self-sustaining efforts of the California Wind Energy Collaborative. Ultimately, the collaborative will provide expertise to the Commission to help supplement and enhance wind energy planning and development programs specific to California.

Additional goals include:

- Support the existing wind industry by maintaining an electronic wind performance database.
- Develop a wind energy technician training plan.
- Prepare investigative white papers reporting on current industry issues and research scenarios.
- Assist in the development of a state wind anemometer loan program plan.

This project supports the PIER Program objectives of:

- Improving electricity reliability/quality/sufficiency of California's electricity by:
 - Ensuring California maintains a competent and current wind energy support base.
 - Providing immediate expertise to PIER planning activities in areas pertaining to wind energy technology from design, operation/maintenance, electrical generation and management.
 - Providing immediate expertise to evaluate and assess industry requests.
- Strengthening the California economy by:
 - Supporting research and development by gathering and disseminating data pertinent for the further development of wind technologies.
 - Creating new jobs/position and training new technicians and engineers to support the wind industry.
- Providing greater choices for California energy consumers by providing current, reliable facts on the wind industry, dispel myths about wind energy, and provide better

understanding of the wind industry's capabilities by combining energy resources through case studies and optimization scenarios.

Proposed Outcomes:

1. Establishment of the California Wind Energy Collaborative as a forum for a coordinated approach to deal with wind related technologies beneficial to California's unique needs.
2. Help plan guidelines for a statewide wind-engineering technician training program to ensure California maintains a competent support base.
3. Investigative white papers that offer plausible approaches to optimizing wind plant facilities including RPS integration issues, storage technologies, wind trend analysis and turbine performance and power trends.
4. Assistance in planning for a state wind anemometer loan program and personnel to support the effort.
5. Continue enhancing the electronic reporting efforts of the Wind Project Performance Reporting System (WPRS).
6. Support consumer education efforts.

Project Status:

The California Wind Energy Collaborative established an office on the UC Davis campus in the first quarter of 2002, and is currently serving as a focal center for wind energy related developments in the state. During its first year, the Collaborative established and held semi-annual meetings of an advisory board of wind industry professionals, the wind energy research community and government representatives working on wind energy issues at the state and federal levels. In December of 2002 and 2003, the Collaborative hosted the Wind Industry Forum, which was well received by the attendees. The Collaborative continues to maintain and develop the electronic Wind Performance Reporting System (WPRS). Five scenario-based white papers have been completed. These include: Wind Speed and Electric Power Trends, Value of Back-up and Energy Storage, Renewable Generation Integration Cost Analysis, Wind Facts and Fiction, Geothermal Integration Issues for RPS. In response to industry needs, the Collaborative provided initial plans for a technician training program and wind anemometer loan program. Future activities of the Collaborative will be funded under a work authorization under the CIEE Master Research Agreement. Information regarding the California Wind Energy Collaborative, including the electronic WPRS and Wind Forum proceedings can be found at <http://cwec.ucdavis.edu>.

Clean Power Estimator

Contract #: 500-01-029

Contractor: Clean Power Research

Subcontractors: Clean Power Research

Contract Amount: \$43,500

Contractor Project Manager: Tom Hoff (707) 224-9992

Commission Contract Manager: George Simons (916) 654-4659

Status: Active

Project Description:

The goal of this project is to assist California consumers in evaluating the economic feasibility of cool roofs (primarily roofs with high solar reflection and high thermal emittance), radiant barriers, and building integrated photovoltaics (BIPV) by:

- a) Documenting the energy impacts associated with the various products based on existing research results.
- b) Constructing an analytical method that quantifies the electricity savings based on these research results.
- c) Integrating the analytical capability into the Commission's version of the Clean Power Estimator program.

This project supports the PIER Program objective of:

- Improving the energy cost/value of California's electricity by enabling consumers to assess the benefits of cool roofs, radiant barriers, and BIPV systems to determine if they want to purchase such technologies to decrease heat gain in their building structure or generate their own electricity.

This project will accomplish this goal by extending the capability of the Commission's version of the Clean Power Estimator tool to be able to assess the economic benefits of cool roofs, radiant barriers, and BIPV. The updated tool will be made available to California consumers on the internet-based Clean Power Estimating Tool.

Project Status:

The Contractor has completed the tasks of documenting the energy impacts associated with the various products based on existing research results and constructing an analytical method that quantifies the electricity savings based on these research results. The last task of integrating these into the web based Clean Power Estimator tool has been completed. The project results are available on the web at: <http://www.consumerenergycenter.org/renewable/estimator/index.html>

This project has completed all of its requirements.

Co-Production of Silica from Geothermal Fluids

Contract #: PIR-00J-003

Contractor: Lawrence Livermore National Laboratory

Subcontractors: Department of Energy : Mammoth Pacific LP : Caithness Power : Covanta Power

Contract Amount: \$669,683

Match Amount: \$167,420

Contractor Project Manager: William L. Boucier (925) 423-3745

Commission Contract Manager: Pablo Gutierrez (916) 654-4663

Status: Active

Project Description:

The purpose of this project is to develop commercial technologies to efficiently extract silica from geothermal fluids. The extraction of silica will favorably impact the economics of geothermal power generation through the sale of the mineral by-product. Benefits may also be realized from the generation of additional energy and the reduction of operating and maintenance costs at power plants through a reduction in silica scaling. Silica removal reduces the need for costly new injection wells. When left in the reinjected fluids, silica will precipitate in the reinjection pipeline and subsurface rock formations, causing equipment and well plugging. Extracting silica prior to reinjection has no negative environmental impact and allows spent geothermal fluids to be used as a potential source of irrigation or industrial water, rather than reinjected.

This project supports the PIER Program objective of:

- Improving energy cost/value of California's electricity by sale of the mineral by-product from geothermal fluids. Benefits may also be realized by the generation of additional energy and the reduction of operating and maintenance costs at power plants through the reduction in silica scaling.

Proposed Outcomes:

This research will develop processes for producing silica from geothermal fluids that are suitable for use in a number of commercial products. Lawrence Livermore National Laboratory's (LLNL) work will focus on studies of the precipitation and post-processing techniques that will result in silica of the appropriate purity, particle size, and surface characteristics for specific industrial uses. The key properties of precipitated silica that must be controlled for it to be useful include: surface area, particle size, and density, pore size, pore size distribution, and degree of agglomeration.

Successfully marketing amorphous silica will require:

1. Matching the physical and chemical properties of silica used in a particular market.
2. Identifying markets that are large enough to absorb the volume of geothermal produced silica without being overwhelmed.
3. Obtaining a price for produced silica such that the silica extraction process is economic.

Project Status:

During 2003, LLNL conducted a series of silica extraction field tests at Mammoth Pacific's LP Inc. geothermal power plant located at Mammoth, California. After unsuccessful initial attempts to extract silica from the discharged fluids, it was concluded that the low silica content prevents rapid and economic extraction of the silica. As a result, LLNL decided to lease a reverse osmosis (RO) pilot unit (8 gpm) that could successfully be used to elevate the concentration of silica in the

brine from 250 ppm to 500-700 ppm. The RO unit separates the geothermal fluid into two components: the clean water or permeate which was diverted away from the process and the concentrate stream which was directed to the reactor vessel for silica extraction tests.

The RO unit was installed and worked successfully. Additional field tests were carried out using the RO unit. Samples of the precipitates from the field tests have been sent to Activation Laboratories Ltd. for analysis. Silica samples were also sent to Byers Rubber Consulting for a tire rubber performance test. Tests results are expected before April, 2004.

Although LLNL generated silicas with properties similar to commercial silicas used in such markets as rubber fillers and polishing agents, they have not been able to efficiently capture the silica using 200 nm cartridge filters located downstream from the stirred reactor. After a review of available filtering methods, LLNL decided to use tangential flow filtration. Tangential flow filters should allow a much higher percentage of colloidal silica to be removed and thus increase the amount of material that can be returned for use in marketing tests. Additionally, LLNL is in the process of constructing a new higher volume reaction vessel that will achieve longer residence times and higher flow rates. Larger flow rates are needed in order to collect larger masses of silica precipitates needed for the marketing tests.

Field work is expected to resume in April 2004, when a larger reaction vessel and a tangential flow filtration unit for capturing silica can be purchased and installed.

This project is approximately 75% complete. LLNL anticipate the conclusion to this project by October 2004.

Evaporative Cooling of Geothermal Power Plants with Recycled Water

Contract #: PIR-00J-002

Contractor: Mammoth Pacific LP

Subcontractors: Mammoth Community Water District

Contract Amount: \$1,000,000

Match Amount: \$4,571,678

Contractor Project Manager: Robert Sullivan (760) 934-4893

Commission Contract Manager: Pablo Gutierrez (916) 654-4663

Status: Active

Project Description:

The purpose of this project is to increase power production of the combined geothermal power plants in the Mammoth Pacific Limited Partnership (MPLP) by up to 10 MWe during the summer months. This will be done by modifying the existing power plants to utilize evaporative cooling. The MPLP owns and operates three geothermal binary power plants (G1/G2/G3) with a combined on-line power generation of 32 MWe.

Phase 1 testing will include the evaluation of three different evaporative cooling technologies and the evaluation of two different sources of water. Phase 2 will construct permanent power plant modifications and the needed support systems to utilize evaporative cooling. The three evaporative cooling technologies that will be tested are:

- 1) Swamp cooler technology utilizing a thick eight inch thick honeycombed material.
- 2) Wetted pad technology utilizes a two inch thick honeycombed material.
- 3) Fogger nozzles and no filter media.

Phase 2 will consist of using geothermal fluid as a source of evaporative cooling fluid and/or the use of secondarily treated wastewater as a source of evaporative cooling. The geothermal fluid and wastewater will be used during the summer months for evaporative cooling.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by enhancing power generation and improving geothermal power plant efficiency.
- Improving electricity reliability/quality/sufficiency of California's electrical system by providing up to 10 MWe of power during the summer months.

Proposed Outcomes:

Phase 1 will result in an evaluation of three evaporative cooling technologies to determine their effectiveness in increasing power production from the G2/G3 power plants during the summer months. These technologies include:

1. Swamp Pad Cooler.
2. Spray Bars with Wetted Pads.
3. Fogger Nozzle.

This evaluation is valuable since summer on-peak power output can be half of the typical winter power output. Lower operation and maintenance costs and ability to maximize power production will be the determining factors in selecting a condenser air-cooling technology. All three technologies were tested at the G2/G3 power plants.

Phase 2 will result in an engineering analysis and the construction, testing of a geothermal fluid conveyance system. Financial considerations include cost of geothermal fluid chemical treatment,

operation and maintenance costs, construction, project financing, capital costs, etc. A permanent chemical treatment system will be constructed to supply reclaimed geothermal fluid during the summer months for the G-1/G2/G3 evaporative cooling system.

Project Status:

The task of determining the impacts from the three evaporative cooling technologies on power plant economics, operations and efficiencies has been completed. MPLP has completed design and installation of a swamp cooler technology (U2000 Munters) media mounted on a series of “V” type adjustable frames. The U200 system will provide inlet air cooling. Swamp cooler technology utilizing a thick eight honeycombed material, Three 40 hp pumps were installed for water circulation and a submersible pump was installed to handle the blowdown to the injection well. Plant operating parameters have been documented including: power output, turbine back pressure, brine flow, brine temperature, ambient temperatures, inlet air temperatures, wind speed, velocity, dew point, dry-bulb temperature and air humidity. This information was then compared to historical plant operating data to assess the efficiency of each evaporative media technology. The evaporative cooling media were designed from recorded observations. In addition, MPLP developed a geothermal fluid sampling regiment according to U.S. EPA and ASTM lab standards.

MPLP is conducting an economic analysis to determine the environmental impacts of the reclaimed geothermal fluid as evaporative cooling fluid. The economic analysis also includes an assessment of potential hazardous waste disposal under State of California Title V, Hazardous Waste Regulations.

This project is approximately 30 % complete. MPLP anticipates the conclusion of Phase 2 during the summer months of 2004.

Hydrogen-Assisted Lean Operation for Biogas Reciprocating Engines

Contract #: PIR-02-001

Contractor: TIAX LLC

Contract Amount: \$497,811

Match Amount: \$133,000

Contractor Project Manager: Larry R. Waterland (408) 517-1572

Commission Contract Manager: Valentino Tiangco Ph.D. (916) 654-4664

Status: Active

Project Description:

The purpose of this project is to develop and demonstrate a NO_x control technology that can be applied to biogas-fueled reciprocating internal combustion engines to achieve greater than 90 percent NO_x reductions from the state-of-the-art for lean-burn biogas-fueled engines that is currently designated best available control technology (BACT). The technology relies on the addition of hydrogen-containing biogas reformat to the engine's biogas fuel, which in turn allows the lean limit of the combustion process to be extended to much higher air/fuel ratios.

By extending the lean combustion limit and operating the engine under leaner conditions, peak cylinder flame temperatures are decreased and extending the lean combustion limit and operating the engine under leaner conditions substantially reduces NO_x emissions. The hydrogen containing reformat will be produced by reforming a portion of the biogas fuel in an autothermal reformer onsite. The project will develop this technology, fabricate a reformer, install the reformer and a 75-kW engine-driven co-generation unit at the Marysville landfill of Norcal Waste Systems, and demonstrate the performance of the technology operating on biogas fuel/ feed at the host site.

This project supports PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.

Proposed Outcomes:

1. Successful development and demonstration of a landfill gas autothermal reformer with a 70 percent conversion efficiency. Conversion efficiency is defined as (H₂+CO) produced/CH₄ fed.
2. Demonstration of an engine heat rate of 10,000 Btu/kWh and CHP heat rate of 6,017 Btu/kWh.
3. Use the landfill gas reformat to reduce IC engine NO_x emissions to 0.032 g/bhp-hr (0.10 lb/MWh) without the CHP credit. With the CHP credit, NO_x emissions will be 0.02 g/bhp-hr (0.06 lb/MWh).
4. Make a best effort to achieve the central station power plant Best Available Control Technology NO_x level of 0.02 g/bhp-hr (0.06 lb/MWh) without the CHP credit.
5. At production volumes of approximately 100 units per year, a reformer capital cost of \$300/kW (where kW is H₂ + CO thermal equivalent on an LHV basis).
6. Installed capital cost of commercial system less than 1000 \$/Kw.
7. Simple payback period less than 3 years.

Project Status:

This project is currently underway. Kickoff meeting was held on March 13, 2003.

The demonstration engine/generator was obtained from Hess Microgen consisting of a Ford Power Products Model WSG-1068 V10 engine powering a 78 kW induction generator with switchgear allowing interconnection to the grid. The engine has been modified, turbocharged and aftercooled. While the Contractor was awaiting approval from PG&E to install and interconnect the unit to the PG&E grid, the Hess Microgen engine/ generator system was shipped to the TIAX engine laboratories in Cambridge, Massachusetts in October 2003 for the scoping tests and engine/reformer model simulations. The Contractor is expected to be on schedule in 2004.

Landfill Gas Fired 250 kW Microturbine

Contract #: PIR-02-002

Contractor: Stearns, Conrad and Schmidt Consulting Engineers, Inc.

Subcontractors: Ingersoll-Rand

Contract Amount: \$450,000

Match Amount: \$499,047

Contractor Project Manager: Jeffrey L. Pierce (562) 426-9544

Commission Contract Manager: Prab Sethi (916) 654-4509

Status: Active

Project Description:

The purpose of this project is to install and demonstrate a 250 kW beta microturbine on landfill gas. At the present time, the largest microturbine that has been proven in landfill gas service is a 70kW microturbine.

The introduction of a larger microturbine to the landfill gas market would: 1) reduce total installed of the technology on a \$/kW basis, and 2) to enable the technology to be used for larger projects and, as a consequence, increase microturbine technology's distributed generation market share in the capacity range (500 kW to 2,000 kW) – a range which is currently ceded to reciprocating engines. Ingersoll-Rand will supply the 250 kW microturbine. Ingersoll-Rand is currently in the microturbine business and is currently manufacturing and selling a 70 kW microturbine. Ingersoll-Rand has marketing, distribution and service network and a microturbine manufacturing capability, which will support immediate commercial deployment of a successfully demonstrated beta unit.

This project supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by providing a low-cost high-efficiency distributed power generation engine that runs on LFG.
- Improving the environmental and public health costs/risk of California's electricity by efficiently using LFG to generate electricity (removing this potent greenhouse gas from the environment) while limiting the engines emissions to very low levels.

Proposed Outcomes:

1. Introduction of a make market-ready-250 kW microturbine which is able to be fired on landfill gas.
2. Increase the number of landfill gas-fired microturbine projects in the 200 kW to 500 kW size range.
3. Position microturbines to compete with landfill gas-fired reciprocating engines in the 750 kW to 1,500 kW size range, reducing NO_x emissions by 800 tons per year on a statewide basis.
4. Add as much as 30 MW of otherwise unrealized landfill gas-fired microturbine capacity in California within the next five years (versus the currently installed and under construction 2.5 MW).
5. Reduction of capital cost of landfill gas-fired microturbine installations by 20 percent to 25 percent.
6. Reduction of cost of power from landfill gas-fired microturbine projects by 20 percent to 25 percent.

7. Attainment of project's stretch goals as indicated below:

Affordability (COE)	\$0.048/kWh
Energy Recovery System Capital Cost	\$1,600/kW
Prime Mover Capital	\$800/kW
Prime Mover Lifetime	10,000 hours +
Capacity Factor	93%

Project status:

Project kickoff meeting was held on August 6, 2003 in Sacramento. The following is the description of the progress on this project:

1. A kick off meeting was held on August 6, 2002 to review scope of work and administrative items.
2. The microturbine will be located in Burbank Landfill. City of Burbank has approved general arrangement plan for location of the microturbine.
3. SCS has submitted permit application with the South Coast Air Quality Management District (SCAQMD) for their review.
4. Ingersoll-Rand is proceeding with the fabrication of the microturbine.
5. The Contractor is working on the design work as well as draft test plan.

Ocean Wave Energy Resource Assessment for California

Contract #: 500-01-018

Contractor: California State University, San Diego

Subcontractors: Neptune Sciences

Contract Amount: \$120,000

Contractor Project Manager: Asfaw Beyene (619) 594-6207

Commission Contract Manager: David Navarro (916) 654-4618

Status: Active

Project Description:

The purpose of this project is to conduct an assessment of ocean wave energy resources off California's coast and determine the technical, economic and environmental feasibility of using ocean wave energy systems to provide electricity to the state's electricity system. In addition, the project will identify potential sites best suited for ocean wave energy development along the coastline. An earlier evaluation by Pacific Gas and Electric in 1991 estimated an average of 30 to 40 kilowatts per linear meter (kW/m) of available energy in ocean waves off California's northern coast. Harvesting 20% of the northern California's potential wave energy could provide upwards of 4000 MW of electricity.

Under this project, SDSU and Neptune Sciences will:

1. Compile a statistical database of wave characteristics off the California coastline based on buoy measurements and hindcast modeling. The database will include annual wave height, 20-year wave height and wave period by season compiled as a function of geographic location in a one-degree latitude and longitude grid.
2. Estimate the potential energy available from ocean wave resources and include annual energy flux and annual peak energy flux.
3. Identify factors critical to the development and placement of WECs relevant to California's coast and specific geographical conditions including information on the commercial status, technical performance, and cost characteristics of available WEC technologies. Additionally, local and state agency permitting or regulatory requirements associated with deploying WECs off California's coast will be identified.
4. Assess the magnitude of electricity that can be developed from ocean wave energy resources off California's coast, given the technical, economic and environmental considerations and identify the optimal locations for specific and available WEC systems along California's coast.

This project supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by developing a renewable energy technology that can continually feed low-cost electricity into the grid and can be used in remote, site-specific locations where it is prohibitively expensive to bring utility power lines.
- Improving the reliability of California's electricity by helping further the development of a renewable energy technology that can generate electricity 24 hrs/day.
- Improving the environment, public health and safety of California's electricity by providing information that can lead to deployment of an environmentally clean electric generation technology.

Proposed Outcomes:

1. Statistical database of California wave characteristics.
2. Estimation of potential energy to California from ocean waves.
3. Identify critical factors to the development and placement of WECs in California.
4. Site-specific magnitude of energy potential relative to optimal location along California coastline.

Project Status:

The draft final report has been received and is being reviewed.

Powerwheel Demonstration

Contract #: 500-97-037

Contractor: Powerwheel Associates

Subcontractors: Ideal Electric Co. : Electrical Maintenance Consultants : Granger Engineering Services : N. J. Mccutchen, Inc. : ERC, Inc. : California State University : California Polytechnic State University, San Luis Obispo : Johnson's Building Inspection Service

Contract Amount: \$394,156

Match Amount: \$394,000

Contractor Project Manager: Kenneth Broome (650) 529-1810

Commission Contract Manager: Michael Kane (916) 654-7119

Status: Active

Project Description:

The purpose of this project is to prove the technical, economic, and environmental suitability of the Powerwheel technology for converting energy from low-head waterfalls into cost-competitive electricity. A 75 kW Powerwheel will be demonstrated in an irrigation canal and the electricity generated by it will be distributed to nearby agricultural, industrial, commercial, and residential customers through an interconnection with the electricity grid.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity as it is expected that electricity from this source will be more reliable than wind and solar energy.
- Improving the energy cost/value of California's electricity by providing electricity at a lower cost than conventional hydroelectricity costs.
- Improving the environmental and public health costs/risks of California's electricity by displacement of electricity generated by combustion processes resulting in the reduction of exhaust gases of about 250 tons/kW/year of Powerwheel installations. In addition, Powerwheel installations will have no adverse impacts on water quality and may enhance the dissolved oxygen content of the water.

Proposed Outcome:

1. Prove the full-scale technical, economic, and environmental suitability of Powerwheel technology for conversion of the presently wasted renewable energy available in very low-head waterfalls into electricity.

Project Status:

The Contractor lost the original host site for the Powerwheel demonstration. They were able to locate and secure another site but in doing so fell behind schedule. Additional cost was incurred because the Powerwheel unit had to be modified for the new site, leading to the contract being augmented \$194,156 in April, 2002. The Powerwheel was modified and installed in an irrigation canal in Kern county for testing, but soon experienced mechanical difficulties. Repairs were made and the waterwheel was reinstalled, but the machine soon experienced additional mechanical difficulties that precluded field testing. The contractor submitted a draft final report, and the contract should be completed by June 2004.

Renewable Energy Technology Research and Development Program

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power, San Francisco

Subcontractors: Electranix Corporation : Distributed Generation Systems : Microgy : GeothermEx, Inc. : Accurex : ImaginIt : E3 : McNeil Technologies : Aqua Energy : Duke Solar : Millenium Energy : Stirling

Contract Amount: \$5,854,585

Match Amount: \$1,429,181

Contractor Project Manager: Fred Schwartz (415) 554-2425

Commission Contract Manager: Valentino Tiangco Ph.D. (916) 654-4664

Status: Active

Hetch Hetchy Water & Power/SF PUC and Public Renewables Partnership

Program Description:

The purpose of this programmatic renewable project is to advance renewable energy science and technology in ways that allows California public utilities, energy service providers and utility distribution companies to integrate renewable resources as a principal component of their resource portfolios. Hetch Hetchy Water and Power (Hetch Hetchy)/San Francisco Public Utilities Commission (SFPUC) is the prime contractor of this programmatic renewable project. Hetch Hetchy/SFPUC is a member of The Public Renewables Partnership (PRP) (formerly Power Renewable Energy Action Team (PPREAT)). PRP is a broad, new collaboration of California municipal utilities, irrigation districts, potential community aggregators (including non-utility municipalities), and renewable energy developers and others aimed at utilizing renewable resources to help ensure the cost-effectiveness, reliability and resource diversity of California's electricity system. The group works through a collective planning process to investigate the feasibility of and benefits to California's power system from a comprehensive resource-based generation portfolio that includes a significant proportion of renewable energy. Center for Resource Solutions (CRS) is the key subcontractor and program administrator of this programmatic project.

Hetch Hetchy/SFPUC will be the first recipient and customer of the successes of this programmatic renewable project. Currently, San Francisco's electric system is vulnerable to any disruptions. Because the City of San Francisco is located at the end of the peninsula, there is a limited ability to import electricity into San Francisco. All the power coming into the city follows one transmission pathway from an electric substation near the City of San Mateo to another substation near San Francisco's Cow Palace. In December 1998 this infrastructure was disrupted resulting in an economically damaging daylong blackout for parts of the City. During periods of peak demand the City can import over existing transmission lines only about 60 percent of the power needed to meet its needs. Therefore, San Francisco is dependent on the operation of power plants located in the city. Currently, power plants are located at just two sites, Hunter's Point and Potrero, both in southeast San Francisco. The plants located at these sites are old, inefficient, prone to breaking down and many times more polluting than new power plants.

This programmatic renewable project will help accelerate the implementation of the energy plan of the City of San Francisco in providing a coherent framework for assessing San Francisco's opportunities to overcome its electric infrastructure vulnerabilities and assure reliable, affordable and sustainable sources of electricity. The energy plan of the City includes the development of renewable power. The desire to locate renewable energy technologies within the city became evident when San Franciscans voted overwhelmingly for Proposition B, which authorized \$100

million in bonds to finance renewable and efficiency projects in City facilities. In addition, proposition H was also passed, which gives the Board of supervisors the power to issue revenue bonds for renewable and efficiency projects in the private sector.

In this programmatic project, Hetch Hetchy/SFPUC together with PRP will work through a collective planning process to investigate the feasibility and benefits to California's power system from a comprehensive resource-based generation portfolio that includes a significant proportion of renewable energy. Ultimately, this programmatic project will develop long-range renewable power procurement strategies that can compete head-to-head on value with traditional utility power resources. Hetch Hetchy/SFPUC will achieve its goals through a combination of management and technical activities. In particular, by focusing on the advancement of renewable energy technology and science, Hetch Hetchy/SFPUC will ensure the availability of cost-effective renewable energy supply in both the near and long-term. The specific elements of this programmatic renewable project are designed to achieve – in a coordinated fashion – overarching technical and economic objectives of:

- Accelerating the cost effectiveness and value of using renewable energy in the near term as a significant component of a resource portfolio.
- Advancing the development of cutting-edge renewable technologies to ensure the increasing availability of renewable options in the longer term.
- Supporting the application of renewable energy sources in targeted, distributed generation applications to increase grid reliability, reduce transmission and distribution upgrade costs, meet peak demand and reduce transmission congestion, and satisfy customer needs.

This programmatic renewable project consists of one administrative project and 10 linked renewable energy projects with the common aim of utilizing renewable resources to help ensure the cost-effectiveness, reliability and resource diversity of California's electricity system and achieving the overall goal stated above.

The specific projects by emphasis area are listed below:

Emphasis Area 1: Assessing and Targeting Renewable Energy Development

- Project 1.1 Feasibility of Interconnecting Pacific HVDC Intertie
- Project 1.2 New Wind Site ID and Qualification
- Project 1.3 New Geothermal Resource Assessment

Emphasis Area 2: Increasing Affordability of Existing Renewable Energy Facilities

- Project 2.1 Upgrading Existing Geothermal Sites

Emphasis Area 3: Expanding Affordability and Diversity Using Renewable Distributed Generation

- Project 3.1 Distributed Generation Assessment
- Project 3.2 Biomass Project Distributed Generation Value Analysis

Emphasis Area 4: Developing Renewable Energy Technologies for Tomorrow's Electricity System

- Project 4.1 Solar Thermal Parabolic Trough Power Plant
- Project 4.2 Hybrid Biofuel/Natural Gas
- Project 4.3 Energy Storage for Renewable Generation

Emphasis Area 5: Integrating Program Findings to Ensure Broad Replicability

- Project 5.1 Technical Project Performance Integration

This programmatic project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers by providing cleaner sources/choices of energy.

Programmatic Project Status:

This programmatic project is ongoing and within budget.

Early technical work commenced in October 2002. However, implementation of the 7 large technical subcontracts proved more difficult than originally anticipated. The final subcontracts were not completed until spring of 2003. For this reason, most of the Program accomplishments during the first six months centered on development and establishment of many management and administration processes, protocols and reporting systems.

Hetch Hetchy/SFPUC has placed 8 major subcontracts to implement this Program. They are summarized as follows:

Subcontractor	Project(s)	Scope
Center for Resource Solutions	Project 0 and Project 5.1	Management and Administration Support and Technical Integration
Electranix	Project 1.1 and Project 4.3	Transmission Options Analysis and Energy Storage Analysis
GeothermEx	Projects 1.3 and Project 2.1	New Geothermal Resource Assessment and Project Analysis Existing Geothermal Project Enhancement Analysis
Distributed Generation Systems Inc.	Project 1.2	New Wind Resource Assessment and Project Analysis
Energy & Environmental Economics	Project 3.1	Distributed Generation Assessment – Utility Case Analysis
McNeil Technologies Inc.	Project 3.2	Distributed Biomass Value Analysis and Project Development
Solargenix	Project 4.1	Solar Thermal Parabolic Trough – Project Analysis for Public Power
Stirling Energy Systems	Project 4.2	Hybrid Biomass/natural gas Stirling Engine Development

Renewable Energy Technologies

Reporting schedules and protocols were established for all Program participants. Monthly reports are prepared with a common format and include an overall Program summary, a progress report for each technical project, and an MS Project schedule for the overall program. In addition, Match Fund commitment documentation was received from all sources of cost share.

A Research Project Advisory Committee (RPAC) charter and membership was established for the Program as a whole, made up of representatives from the renewable energy private sector, the R&D community, and select members from State and National environmental and energy agencies. Three RPAC meetings were held during Year 1. The committee's recommendations have focused on pushing the Program to remain cognizant of and relevant to State, utility and private sector initiatives associated with California's evolving strategies to help meet the goals of Renewable Portfolio Standard.

Year one annual report that highlights the programmatic project accomplishments was completed and a Critical Program Review Meeting is scheduled on February 6, 2004.

Continued: Renewable Energy Technology Research and Development Program

Emphasis Area 1: Assessing and Targeting Renewable Energy Development

Project 1.1 Feasibility of Interconnecting Pacific HVDC Intertie

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC

Subcontractor: Electranix Corporation

Project Amount: \$311,005

Match Funding: \$96,076

Contractor Project Manager: Fred Schwartz (415) 554-2425,

Subcontractor Project Manager: Dennis Woodford (204) 953-1832

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Elaine Sison-Lebrilla, P.E. (916) 653-0363

Project Description:

The purpose of this project is to explore the technical and financial aspects of interconnection to the Pacific high-voltage DC (HVDC) intertie to bring new wind and geothermal resources to the California market. The HVDC intertie near the California-Nevada border may present opportunities to bring several thousand megawatts of new geothermal and wind resources into California.

The specific project objectives are:

- Determine costs to interconnect a combination of wind and geothermal generation resources to the Pacific HVDC Intertie at single and multiple points near the Nevada-California border in amounts of 500, 1000, 1500, and 2000 MW.
- Determine the available transfer capacity and technical feasibility of any potential AC transmission interconnection points and options that should be considered as an alternative strategy to interconnection into the Pacific HVDC Intertie.
- Determine the optimal interconnection point(s) based on a technical analysis of available geothermal and wind resources near the California-Nevada border.
- Determine the relative costs and advantages of developing a stand-alone AC collector grid for these renewable energy resources versus using the existing AC collector grid.

This project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers by providing cleaner sources/choices of energy.

Proposed Outcomes:

1. A large source of renewable energy will become available for the California market, and because of the nature of this energy and its location, will add to the diversity of energy sources available to the State.
2. A corresponding amount of less environmentally friendly energy will be displaced.
3. Potentially stabilize energy prices in California due to the greater availability of renewable energy resources. Non-volatile energy pricing may be possible from the

proposed renewable energy sources, with a stabilizing effect on overall electric energy pricing in California.

The following performance indices can be used to determine the effectiveness of the proposed interconnection:

- How much new renewable energy generation can be transmitted to customers in Northern California (where the need is greatest) and to Southern California?
- What is the expected return on investment for the recommended transmission option? This will be a main indicator of the project feasibility.
- What percentage of the Pacific HVDC Intertie energy capacity is utilized on a yearly basis? The amount of power and energy that is available to be delivered to Southern California through the Pacific HVDC Intertie will determine the capacity of the renewable resources that can be used, thus impacting the economic effectiveness of the project.
- What environmental impact does the new interconnection have? Although an environmental impact study is not included in this contract, the minimization of new transmission facilities is one measure of environmental impact. The less new transmission, the less environmental impact.
- Added energy from the development of renewable resources will increase the reliability of energy supply to the California power system.
- Benefits to investor-owned utilities might be possible if it is evident that investment opportunities are possible with the development of the renewable energy sources and the associated transmission.
- How much renewable energy can be fast-tracked?

Project Status:

In the past year, Electranix had completed the following tasks and deliverables:

- Pre-feasibility Assessment of DC and AC Transmission Options, completed in April 2003.
- A recommended list of transmission options, completed on April 4, 2003
- Ensure resources and project plan in place and project plan, completed on March 1, 2003

The task to investigate feasibility for interconnecting to the Pacific HVDC Intertie is well under way and with the task report under preparation.

A Critical Project Review was held for this project in March 2003. There were significant comments and questions by the technical review committee that were appropriately addressed by Electranix. The project was approved to move forward consistent with the original project plan.

Work on a deliverable on regulatory issues was postponed in order to accelerate broader evaluation of AC transmission options. As wind, geothermal and solar resource assessment work proceeded through the rest of the contract team, it became evident that transmission analysis associated with power projects outside of the HVDC corridor was of high importance. Characterization of regulatory issues was pushed back to accommodate earlier analysis of AC options.

Overall, the work is about 2 months behind schedule (principally due to contract closure delays). The overall project completion date, originally scheduled for March 2005, should be met.

Continued: Renewable Energy Technology Research and Development Program

Project 1.2 New Wind Site ID and Qualification

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC

Subcontractor: Distributed Generation Systems, Inc.

Project Amount: \$351,750

Match Funding: \$ 95,625

Contract Project Manager: Fred Schwartz (415) 554-2425

Subcontractor Project Manager: Dale Osborn (303) 674-2551

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Michael Kane (916) 654-7119

Project Description:

The purpose of this project is to focus on the identification of new, and developable, wind energy generation sites in California and neighboring states that will have the ability to access the Pacific HVDC Intertie and that may also add value to the generation, and energy storage, capabilities of the Central Valley Project. Hetch Hetchy/SFPUC/PRP will identify the potential for the development of wind resources that would benefit from the HVDC intertie and synergies between the development of these renewable resources and planned or potential natural gas generation near the HVDC intertie. Sites not in proximity to the HVDC line will also be explored. Hetch Hetchy/SFPUC/PRP will also develop an evaluation of potential synergies between wind resource locations and existing planned or potential natural gas plant developments and storage opportunities associated with Western Area Power Administration's (WAPA) Central Valley Project. This assessment of wind resources will build on existing resource maps. The specific objective of this project is:

- Identify and quantify the potential sites, including a ranking of the sites based on project economics. It is expected that at least twenty (20) developable sites will be identified. However, the size of the projects required to support the cost of interconnection to the HVDC Intertie will limit the number of such sites.

This Project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers.

Proposed Outcomes:

1. Over 2000 MW of new renewable generation to supply California.
2. Corresponding reduction in fuel price risk.
3. Offsetting emissions from traditional power generating stations.
4. Increased utilization of existing transmission assets.
5. Economic development activity in excess of \$4,000,000,000.
6. Number of developable sites identified.
7. Total capacity of identified sites.
8. Competitive economics of each site.

9. Synergies with storage, HVDC Intertie and Central Valley Project.
10. Usefulness to PRP members.

Project Status:

Distributed Generation Systems (Disgen) had completed or performed the following tasks in the past year:

- Completed and executed the research subcontract with Hetch Hetchy/SFPUC.
- Conducted detailed map, wind resource and transmission reviews for California, Nevada, Oregon, Washington and Idaho.
- Conducted preliminary site visits in Nevada, California, Oregon and Idaho.
- Selected preliminary sites for wind assessment monitoring in Oregon and northern California.
- Report on sites and synergies, completed on September 4, 2003.
- Analyze and report on potential sites, completed on September 4, 2003.
- Assess sites and issue report on California/Nevada sites, completed on September 4, 2003.
- Assess sites and issue report on Washington sites, completed on September 4, 2003.
- Assess sites and issue report on Oregon sites, completed on September 4, 2003.
- Assess sites and issue report on Idaho sites, completed on September 4, 2003.

The Project is approximately four months behind schedule due to delays in the subcontract amendments and execution. This has necessitated a change in the schedule and term for wind monitoring. In addition, based on the work accomplished and submitted to date, the California Energy Commission and staff have directed Disgen to focus on southern Oregon and California. While a marked redirection from the original Scope of Work, Disgen has amended its plan to accommodate the new direction.

With the contract delays and the enhanced emphasis on California, several Year 1 tasks are behind schedule. Final Met Station locations have yet to be finalized, and therefore no Met Station data is available to the Project as of yet. Work associated with evaluating the Plumas Sierra wind resource has also been delayed.

Continued: Renewable Energy Technology Research and Development Program

Project 1.3 New Geothermal Resource Assessment

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC

Subcontractor: GeothermEx

Project Amount: \$303,458

Match Funding: \$200,000

Contract Project Manager: Fred Weiner (415) 554-2425

Subcontractor Project Manager: Subir Sanyal (510) 527-9876

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Gail Wigget, Ph.D. (916) 653-7551

Project Description:

The purpose of this project is to identify the potential for the development of geothermal resources that would benefit from the HVDC intertie and synergies between the development of these renewable resources and planned or potential natural gas generation near the HVDC intertie. Hetch Hetchy/SFPUC/PRP will also develop a detailed statewide assessment of geothermal resources and an evaluation of potential synergies between geothermal resource locations and existing planned or potential natural gas plant developments. The resource assessment will build on existing resource maps.

The specific objective of this project is to provide a portfolio of well-characterized geothermal resources located within approximately 50 miles of the HVDC Intertie, thus promoting the development of new geothermal power projects and/or an increase in the generating capacity at existing geothermal projects. This will be accomplished by characterizing and quantifying each resource in terms of its minimum and most-likely generating capacity, determining and estimating the costs of exploration and/or development required to reach those capacities, and calculating the associated total development costs and unit development cost (\$/kW installed). The development cost will include transmission tie-in costs, as determined by other participants in this project.

This Project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers.

Proposed Outcomes:

1. Increase the amount of geothermal generation in California by bringing new resources on line or adding capacity at existing resources.
2. Increase in the level of interest and activity in geothermal exploration. The current energy situation in the west has already caused increased interest in the expansion, sale or purchase of existing geothermal facilities.
3. Increase the affordability of geothermal projects by minimizing transmission costs.

4. Increase in generation capacity within 50 miles of the HVDC intertie due to the results of implementing this project are 300 MW, 600 MW and 900 MW within 5 years, 10 years and 15 years, respectively.

Project Status:

Overall, the work on this project should be completed by February 2004. In 2003, the following tasks and deliverables were completed:

- An updated geothermal resource assessment for California and HVDC sites were completed.
- A deliverable on Geothermal Resource Database of Geothermal resource and operation constraint for HVDC Area was completed on April 1, 2003.
- An estimate of generating potential for the non-HVDC area was completed June 2003.
- The task to develop statistical correlations required to estimate drilling costs was completed. A database in Microsoft Access was created to structure results of our data gathering and analysis.
- A deliverable on statistical correlations on drilling costs vs. depth and well productivity vs. temperature was completed on July 16, 2003.
- A task to estimate cost of resource exploration was completed in October 2003.
- Two critical project review meetings were held in the past year and decided to move forward.
- A draft final report outline was submitted in December 2003.

Continued: Renewable Energy Technology Research and Development Program

Emphasis Area 2: Increasing Affordability of Existing Renewable Energy Facilities

Project 2.1 Upgrading Existing Geothermal Sites

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC, **Subcontractor:** GeothermEx

Project Amount: \$204,411

Match Funding: \$ 0

Contract Project Manager: Fred Schwartz (415) 554-2425

Subcontractor Project Manager: Subir Sanyal (510) 527-9876

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Pablo Gutierrez (916) 654-4663

Project Description:

The purpose of this project is to assess the prospects of improving the output of each of the 43 existing geothermal facilities in California, including consideration of improving access to the geothermal resources as well as improving the design and operation of the power plants.

This Project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers.

Proposed Outcomes:

1. Increase the amount of geothermal utilization in California that is achievable without any exploration or new development risk.
2. A set of improvements in resource supply and/or surface facilities that could lead to extra generation from many of the existing power plants for a unit cost below that of developing a new geothermal power project.
3. Increase in generation on the order of 10% may be achieved from the existing facilities, followed by another 10% over the following 5 years. Given the existing plants' total capacity of 2,400 MW, a 240 MW increase in capacity in 5 years and a total increase of 480 MW within 10 years appear reasonable.

Project Status:

This project is continuing according to the schedule.

Continued: Renewable Energy Technology Research and Development Program

Emphasis Area 3: Expanding Affordability and Diversity Using Renewable Distributed Generation

Project 3.1 Distributed Generation Assessment

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC

Subcontractor: Energy and Environmental Economics, Inc. (E3)

Project Amount: \$590,600

Match Funding: \$84,780

Contract Project Manager: Fred Schwartz (415) 554-2425

Subcontractor Project Manager: Snuller Price (415) 391-5100

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Prab Sethi, P.E. (916) 654-4509

Project Description:

The purpose of this project will identify the best locations for distributed generation in local utility distribution systems, including reliability impacts in the analysis, and to assess the impact of load growth and generator uncertainty on the results. The analysis will focus on four distribution systems including systems for the City of Palo Alto Utilities (CPAU), the City of Alameda as well as two others among the PRP member utilities. The overall objective is to accelerate the deployment of renewable energy systems in a distributed generation mode by fully accounting for all benefits.

Contractor will identify at least three potential locations in each system. Reliability impacts will be expressed using estimated incremental changes to expected unserved energy (EUE). Reliability financial value will be expressed using both direct utility distribution company (UDC) cost savings and incremental customer value-of-service (VOS) estimates.

This project includes both distribution engineering and economic analysis components. E3 will complete the economic analysis and Electrotek Concepts as subcontractor to E3 will complete the engineering analysis.

This Project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers.

Proposed Outcomes:

1. Within five-years this project aims to make available a comprehensive and carefully thought-out approach for evaluating the local distribution systems for the best placement of renewable generation resources.
2. Within ten-years this approach will be refined by member and other utilities to become standard industry practice.

3. Within fifteen-years this standard practice will have been in place long enough to improve efficiency in distribution systems state- and nation-wide. This will lead to increased opportunities for renewable generation because of the higher value they receive as well as the decrease in costs of utility delivery systems.

Performance metrics that represent a quantifiable or measurable result from this project work include:

1. Timely reports and presentations.
2. Successful identification of value reflected by feeder. The analysis may find that there are many, or possibly few cost-effective distributed generation opportunities.
3. Work completed on time and under budget.
4. Results and work quality to the satisfaction of the distribution company, Technical Advisors and the Commission.

Project Status:

As of July 2003, E3 has completed the kick-off meetings for all participating utilities SFPUC, Alameda, Palo Alto and SMUD. No work was done with TPUD SMUD was chosen as the replacement. Baseline data reports were completed for SFPUC, Alameda and Palo Alto. Notifications of circuit models for SFPUC, Alameda and Palo Alto were also completed. Engineering and economic screening tools are ongoing for all participating utilities.

The overall project will be completed by mid 2004.

Continued: Renewable Energy Technology Research and Development Program

Project 3.2 Biomass Project Distributed Generation Value Analysis

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC, **Subcontractor:** McNeil Technologies

Project Amount: \$729,569

Match Funding: \$400,000

Contract Project Manager: Fred Schwartz(415) 554-2425

Subcontractor Project Manager: Kevin Degroat (703) 921-1632

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Prab Sethi, P.E. (916) 654-4509

Project Description:

The purpose of this project is to pursue the development and deployment of small modular biomass systems for distributed generation (DG) applications within the service territory of public power utilities. The project will initially focus on conducting research within the territory of the Truckee Donner Public Utility District (TDPUD) as a test case. Based on the results, the analytic approach will then be modified and expanded to other public power utilities. The primary technology focus will be small, modular biomass energy generators in the following applications:

- Microgeneration – 15 – 50 kW systems deployed at load centers with net metering capability.
- Small Generation - 1-10 MW systems generating power for sale to wholesale or retail markets, either as stand-alone plants or in combination with pumped storage or other fossil fuel hybrids.

The primary fuel resource to be targeted is biomass generated from small trees removed during forest restoration and wildfire threat reduction operations. Due to the high costs associated with harvesting and transporting this material, the ability to locate biomass generation close to the supply may yield benefits to both the utility system and the public. Potential benefits include deferred or avoided T&D system upgrades, better local reliability and power quality, fuel supply diversity, improvements in air quality from reduced or avoided emissions, and the value of reducing wildfire hazards by thinning forest areas to generate biomass power.

The objectives of the project are to:

- Determine the appropriate performance characteristics (utility system needs, technology, size and cost) and most suitable locations for small modular biomass generators to provide high strategic value to the electricity system, while simultaneously providing high public benefits.
- Conduct a technology demonstration project in the 15 – 50 kWe range.
- Perform detailed engineering/economic studies of biomass plants in the 1 – 10 MW range.
- Develop data and models that can be used to document the results and apply similar techniques in other regions of the state.

This Project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.

- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Enhancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers.

Proposed Outcomes:

1. Demonstrate the economic and public benefits of using biomass resources that are largely wasted today.
2. Demonstrate the value of deploying modular biomass systems strategically within the electric transmission and distribution system to enhance its benefits.
3. Lead to the development of a modular biomass generating plant that will demonstrate both the technology and a new marketing approach for siting systems that other electric service providers and developers will be able to apply.

The key performance metrics that can be used to measure the success of the project are:

1. Commission and peer acceptance of the analysis tools and methods used to characterize distributed generation opportunities and benefits of biomass generation.
2. Demonstrate of a small modular biomass technology in a grid-connected setting (approximate size 15 kWe). The system will generate power for the on-site load, for export back to the grid, and for a combination of on-site and grid export.
3. Reduce BioMax costs of generation by 25 percent over current state of the art.
4. Develop of a small generating plant (1-10 MW) in size by TenderLand (pending favorable economic and technical analysis).
5. Successful adaptation of modular biomass generating technology, controls and operating procedures identified during the analysis to enhance the distribution generation value of projects.
6. Acceptance by consumers, TenderLand, Truckee Donner or one other public power entity of the technical, business and marketing plans for the project.
7. Public recognition in newspapers and other media outlets of the public benefits produced by the project.

Project Status:

McNeil had conducted the following project activities during the initial year:

- Completed a fully executed contract in mid-April 2003.
- Began the process of gathering baseline utility data.
- Began the process of gathering biomass data in the region.
- Conducted kick-off meeting in Truckee on June 30, 2003.
- Conducted visits of 4 potential host sites for the 15 kW demonstration. The sites include Donner State Park, TDPUD Headquarters, USFS Ranger Station, and Truckee Recreation District Field Office.
- Confirmed that TDPUD is willing to demonstrate 15 kW biomass system.
- Began the process of gathering baseline utility data.
- Began the process of gathering biomass data in the region. Met with USFS personnel during the June 2003 trip to collect data on planned thinning projects near Truckee.
- TDPUD Board approved that they will participate in the project. They will support the demonstration at a community site.

The project is currently ongoing and behind schedule on all tasks and deliverables.

Continued: Renewable Energy Technology Research and Development Program

Emphasis Area 4: Developing Renewable Energy Technologies for Tomorrow's Electricity System

Project 4.1 Solar Thermal Parabolic Trough Power Plant

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC

Subcontractor: Duke Solar

Project Amount: \$630,804

Match Funding: \$157,701

Contract Project Manager: Fred Schwartz (415) 554-2425

Subcontractor Project Manager: Gilbert Cohen (919) 871-0423

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Hassan Mohammed (916) 651-9855

Project Description:

The purpose of this project is to perform a pre-feasibility evaluation of advanced solar thermal power plants that will lead to an aggregated Power Purchase Agreement (PPA) from a group of California municipal utility companies. The plants, to be developed as IPP projects subsequent to the completion of this effort, are to consist of a series of advanced parabolic trough solar thermal power facilities at California sites totaling 1000 MWe, with emphasis on supply to the Pacific HVDC intertie. The future plants would be built in time-sequenced phases, each consisting of a single or complex of plants from 50 to 200 MW in size. A key objective of this evaluation will be to determine the optimum approach for development.

The technical objectives of this project are to:

- Evaluate advanced solar field and system configuration concepts suitable for imminent commercial implementation.
- Determine the required power capacities and production schedule to contribute to aggregated system demand requirements using dispatchable solar thermal power plants.
- Identify the optimal and alternative sites for the selected solar thermal power plant facilities.
- Evaluate the prospect of interconnection to the Pacific HVDC intertie in the Owens Valley/Mojave Desert corridor in particular.

The economic objectives of this project are to:

- Review available system benefit charges, subsidies, production credits, green power premiums, and other renewable incentives.
- Evaluate all siting requirements and establish appropriate financial assumptions.
- Perform initial cost, performance, and economic analyses of promising solar thermal power plant options and configurations.
- Establish schedule for plant design, construction and operation.
- Explore various business and ownership models.
- Develop, working with the Muni's, a draft PPA for implementation.

This project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.

Renewable Energy Technologies

- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers.

Proposed Outcomes:

1. Deliver new site selection data for California for large-scale solar thermal power plants near the Pacific HVDC intertie or elsewhere.
2. Propose a construction plan for a sequence of plants up to a total of 1000 MW.
3. Show the performance and cost reductions that may be derived from a next series of projects, develop a new PPA model for large-scale solar thermal power plants.

Project Status:

Work is ongoing on the project and was delayed by several months due to delays in subcontract completion. Work began in September 2002, with early focus on the Utility Seminars. Seminars were held in northern and southern California in the summer of 2003. Permit requirements, technical option report and business model reports have been completed for review and was discussed in the Critical Project Review Meeting held on January 27, 2004. The remaining tasks on the project are expected to be completed by mid 2004.

The Public Utilities Commission of Nevada had approved a power purchase agreement (PPA) between SolarGenix and Nevada Power Co. of Las Vegas and Sierra Pacific Power Co. of Reno to build a 50 MWe trough plant and produce 100,000 MWh per year for a 20-year period.

Continued: Renewable Energy Technology Research and Development Program

Project 4.2 Hybrid Biofuel/Natural Gas

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC

Subcontractor: Stirling Energy Systems, Inc.

Project Amount: \$525,000

Match Funding: \$174,999

Contract Project Manager: Fred Schwartz (415) 554-2425

Subcontractor Project Manager: Steve Levine (602) 957-1818

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Valentino Tiangco, Ph.D. (916) 654-4664

Project Description:

The purpose of this project is to focus on the development of bio-fueled and natural gas cofired modular Stirling engine systems for distributed and on-site generation applications. The objectives of this project are to complete research and development for a demonstration prototype dual-fueled, bio and natural gas, Stirling engine(s) generator set. This system will have a generating capacity of approximately (90) kilowatts capable of operating in accordance with California and Federal interconnection and emissions standards and further to establish parameters (technical and economic) for successful commercialization of the dual fuel prototype(s).

Preferred fuels are expected to be biogas from wastewater treatment plant flare off-gas and landfill gas. For solid waste and high sulfur-content biogas fuels, 2-stage burners may be required. For larger output systems, gas processing may be required or economically advantageous. At a minimum, the fuels that will be tested include, landfill gas and natural gas.

This Project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers.

Proposed Outcomes:

1. Develop a modified external burner section capable of operating on available bio-fuels within program design and economic parameters.
2. Integrate the modified external burner section with a Stirling engine with a generating capacity of approximately 90 kilowatts for use as an on-site distribution generation demonstration prototype unit.
3. Field Test the prototype/demonstration unit.
4. Establish economic model for markets conditions with respect to price competitiveness (as compared to other green options, incentive driven, blended green offerings). Low production price target is \$1500 per installed kWh, \$400 mass production scale. These numbers are conservatively consistent with the NASA Mod II report for natural gas fired systems.

5. Financial and business model for product offering in California market (5 year, 10, year) roll out. Goal is to achieve results capable of attracting a strategic co-investor, production vendors and distributors. This would avoid additional substantial funding by PIER.
6. Establish teaming agreements for product/systems with PRP members and partners, prospective co-investors, vendors and distributors.
7. Projected Alpha commercial unit has a target date of 12/31/02.
8. Projected installed units approximately (10) units and (1) MW by 12/31/03.
9. Projected (10) MW installed at year (5).
10. Projected (50) MW installed by year (10).
11. Projected (250) MW installed by year (15).

Project Status:

The preliminary burner design report was prepared and completed. The design of the burner assembly and fabrication of the Stirling Engine major components is progressing. Other activities performed in the past year were:

- Arranged for free-burn tests at Arizona State University's Combustion Lab.
- Completed 50% of test rig design.
- Modified the burner loop design and fabricated a new top assembly and nozzle.
- Prepared a draft Business Plan Report for review.

Overall, the project is behind schedule due to identification of additional work.

Continued: Renewable Energy Technology Research and Development Program

Project 4.3 Energy Storage for Renewable Generation

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC

Subcontractor: Electranix Corporation

Project Amount: \$318,728

Match Funding: \$82,837

Contract Project Manager: Fred Weiner (415) 554-2425

Subcontractor Project Manager: Dennis Woodford (204) 953-1832

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Elaine Sison-Lebrilla (916) 653-0363

Project Description:

The purpose of this project is to address how the application of energy storage capability might increase the economic effectiveness and value of wind and PV renewable energy sources. A particular focus will be placed on potential interactions with the HVDC intertie project, but the methods used will also apply to other possible development locations. In specific terms, the project will look at:

- Realistic, available energy storage options that will be quantified in terms of their cost effectiveness. Those energy storage options that are not cost effective will be discarded.
 - The energy storage options that will be considered will include but not be limited to the following:
 - Existing hydroelectric resources.
 - Batteries.
 - Superconducting magnetic energy storage.
 - Regenerative fuel cells.
- Sizing and location of new energy storage facilities if they are cost effective.
- Possible hydroelectric generating companies that might be amenable to a contract for energy storage.

This Project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.
- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers.

Proposed Outcomes:

1. A corresponding amount of less environmentally friendly energy will be displaced.
2. Energy prices in California could be stabilized due to additional generation. Non-volatile energy pricing will be possible from the identified renewable energy sources, with a stabilizing effect on overall electric energy pricing in California.
3. Added energy from the development of renewable resources with energy storage will increase the reliability of energy supply to the California power system.
4. Provide a technical assessment on the energy storage options for the renewable energy resources identified for future development in the California -Nevada border regions.

5. Economic viability will also be determined for the various energy storage options and recommendations for future developments will be made. Such recommendations cannot be forthcoming at this stage unless this project is completed.
6. A profitable case made by this project for use of energy storage in conjunction with renewable energy sources will open up the way for a schedule of development as laid out below.

Project Status:

The optimization model for use of energy storage such as existing hydro dams for intermittent wind generation has been completed and a graphical user interface has been developed. Transmission congestion is not included in this model. A user's manual has also been completed.

Work continues to assemble data for the energy storage model.

Continued: Renewable Energy Technology Research and Development Program

Emphasis Area 5: Integrating Program Findings To Ensure Broad Replicability

Project 5.1 Integrating Program Findings to Ensure Broad Replicability

Contract #: 500-01-042

Contractor: Hetch Hetchy Water and Power/SF PUC, **Subcontractor:** Center for Resources Solutions

Project Amount: \$508,033

Match Funding: \$40,643

Contract Project Manager: Fred Schwartz (415) 554-2425

Subcontractor Project Manager: Ray Dracker (415) 561-2135

Commission Project Manager: Valentino Tiangco, Ph.D. (916) 654-4664

Commission Technical Lead: Valentino Tiangco, Ph.D. (916) 654-4664

Project Description:

The purpose of this project is to ensure that the technical findings of this research and development effort are integrated with one another and delivered to PRP electricity service providers such as Hetch Hetchy/SF PUC that can best utilize the work in their ongoing program efforts.

The technical objectives of this project are to:

- Maximize the value and impacts of the HVDC Intertie assessment by integrating the resource assessment and project planning work in the Bulk Power tasks. There is a large quantity of commercial-quality wind, solar and geothermal resource close to the HVDC line in Oregon, Nevada and California. It is expected that a large (500 MW – 2000 MW) tap will be required to ensure cost effectiveness.
- Furthermore, it will be critical to have a portfolio of project options to feed into the Line to provide for an optimal loading (mixing the right quantities of wind and solar, which have complimentary seasonal and diurnal production profiles, with some dispatchable geothermal, will be critical to overall economic viability). The integrated output of a multi-component renewable energy mega-project will need to fit into the existing seasonal and daily load on the Line.

The economic/business objectives of this project are to:

- Feed resource, cost, and other project or technology specific PIER Project results into the on-going Hetch Hetchy/SFPUC/PRP utility resource and project planning activities. PRP member PV initiatives, other distributed generation initiatives, and bulk renewable RFP initiatives are underway and are expected to gain momentum throughout the course of this PIER Program. Feeding the economic and business results of this Program directly into the utility planning and procurement processes will ensure high quality renewable energy implementation.

This Project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.

Renewable Energy Technologies

- Advancing research and development of renewable energy technologies and finding renewable energy applications that benefit California ratepayers.

Proposed Outcomes:

1. Economically-viable HVDC/Bulk Renewables project combination.
2. Integrated distributed generation assessment resulting to successful demonstration and deployment.

Project Status:

Two Bulk Power Integration meetings have been held in the past year. One Distributed Generation Integration meeting was held 2003. The first bulk power integration and distributed generation integration reports were completed in March and July 2003, respectively.

CRS maintained an ongoing dialogue with California Utilities. Planning for the RPS is a priority for many utilities.

SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Contract #: 500-00-034

Contractor: Sacramento Municipal Utility District

Contract Amount: \$13,649,499

Match Amount: \$10,549,413

Contractor Project Manager: Sid Bhatt (650) 855-8751

Commission Contract Manager: Joe McCabe (916) 654-4412

Status: Active

Program Description:

The purpose of this contract is to co-fund nineteen research, development and demonstration (RD&D) projects that will make renewable energy technologies part of a more affordable and diverse electricity system in California over the next 5, 10 and 15 years. The Sacramento Municipal Utility District (SMUD) is administering the project. The intent is to develop effective partnerships between market-oriented electricity suppliers (like SMUD) and renewable energy technology developers. The combination of market-oriented prime contractors directing the development activities of technology experts provides a high likelihood of successful market adoption of advanced renewable energy services and products.

Over the past several years, SMUD has demonstrated a national leadership role in photovoltaics (PV) by learning from a structured manufacturing and installation approach that has the potential to significantly reduce PV system costs. The SMUD program builds off its successes in the photovoltaic arena by continuing advancements to PV systems targeted for the residential and commercial sectors. However, the SMUD program expands its PV focus to include wind and biomass resources available in the SMUD territory. Fourteen of the nineteen projects concentrate on photovoltaics (PV) technologies and markets. The SMUD PV projects include the following:

- Advanced PV mounting systems that will enable PV systems to be more easily and cost effectively installed on a variety of roof types, while still employing a structured manufacturing and installation approach. This effort will significantly expand the number of customers who can employ PV systems to help meet their electricity needs.
- Building integrated PV technologies are being developed that will increase the value of PV systems to customers by combining energy efficiency features, an extended roof life and electricity generating capabilities into a single system package.
- Using PV in combination with advanced space cooling systems in ways that enable electricity customers to meet all their cooling needs during California's hot summer peak times.
- Strategies and analytical tools for developing future PV systems that directly benefit electricity customers, while also generating significant system-wide cost savings by deferring expensive transmission and distribution upgrades or expansions.

This programmatic contract supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by making renewable energy technologies part of a more affordable and diverse electricity system.
- Improving the reliability/quality of California's electrical system by accelerating the development of renewable distributed generation systems in high-need areas of the state.
- Providing greater choices for California consumers by increasing the use of renewable energy technologies in California's electricity mix.

In addition to its advanced PV projects, the SMUD program also involves development of innovative biomass, wind, and concentrating solar electricity systems. Projects include:

- Biomass work by SMUD that follows an earlier funded California Energy Commission project by Yolo County. This project emphasizes increasing the affordability of electricity generated from landfill gas. Using special landfill designs and operating techniques, Yolo County successfully demonstrated a way to accelerate the decomposition of organic materials in landfill control cells, resulting in a three-fold increase in landfill gas. This method of using landfills as biological reactors significantly increases the cost-effectiveness of generating electricity from California landfills. The SMUD project at Yolo County will extend Yolo County's earlier work on accelerated decomposition to a full-scale landfill and help bring this technology into the marketplace. With over 300 active landfills in California, the accelerated decomposition approach could help considerably increase our ability to use landfill gas to generate more affordable electricity.
- Investigating ways to enhance use of wind resources to help make electricity more affordable and diverse. Under a subcontract to Dehlsen Associates, SMUD has developed and is testing a commercial-scale 1.5-megawatt wind turbine geartrain composed of a series of small, parallel gearboxes and generators. By distributing the geartrain components, Dehlsen can lessen the amount of torque (and therefore stress) applied to any one part of the geartrain. This means less overbuilding of geartrains, which in turn means lower geartrain capital costs. In addition, lower stress means lower maintenance costs. Overall, Dehlsen expects the new geartrain to cost forty percent less than presently available geartrains.
- Science Applications International Corporation (SAIC) has developed and is demonstrating a 20-25 kW concentrating solar dish/Stirling system and a concentrating solar dish/photovoltaic system that can generate more electricity per square foot of collection area and may better address industrial electricity needs. NREL believes that a PV concentrating system currently can achieve eighteen percent solar-to-electrical power efficiency and, in the next few years, can achieve efficiencies exceeding thirty percent. The higher power efficiencies will make it possible for industrial users to harness solar energy to help meet their electricity needs.

Programmatic Project Status:

Extensive review of the program and the projects from industry experts is ensuring that the projects are proceeding in a positive direction. As of January 2004, the Renewable Programmatic Advisory Committee, and all but three of the projects, have held Critical Project Review (CPR) meetings. A few of the project have held multiple CPR meetings. These CPRs have given valuable outside independent expert advice with favorable results. A 2002 annual review of the programmatic received a positive recommendation to proceed from the PIER Research Committee. A 2003 Annual report was received.

All projects have signed sub-contracts, held kickoff meetings, and are proceeding with RD&D activities except for the Oakridge National Laboratories Hybrid Lighting demonstration project (#4.4), scheduled for installation in 2004.

Some projects have finished early 2003: Utility System Capacity and Customer Demand Value of PV by NREL (#1.3), Flat Roof Mounting Approaches by RWE- Schott Solar (# 3.4) are already completed. All projects are expected to be completed by the end of 2004.

Public and private web based project information is available at www.smud.org/pier. The projects by emphasis area are on the following pages.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 1.1 Technology Assessment for Advanced Biomass Power Generation

Contract #: 500-00-034

Contractor: SMUD Programmatic-Project # 1.1 UC

Project Amount: \$158,070

Match Funding: \$20,120

Contract Project Manager: Bryan Jenkins 530-752-1422

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Valentino Tiangco, 916-654-4664

Project Description:

A technical assessment will be conducted of advanced and novel power generation concepts from biomass to increase the efficiency of conversion and improve the opportunities for agricultural and solid waste fuels not currently utilized in California for reasons of ash fouling, emissions, or cost. The assessment will include a literature review and industry survey of facilities and applications throughout the world that will:

- Compile of plant design concepts and operating characteristics.
- Provide technical and environmental performance, costs, and problems.
- Identify fuel types.
- Compare these findings with current technologies in California.

Promising designs and concepts will be identified along with enhancements needed for potential application in the Sacramento region to meet technical and environmental constraints.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by determining the feasibility in the Sacramento region of promising commercial biomass power generation systems used in Europe and elsewhere, including solid fueled, gasification, liquefaction, and landfill gas technologies.
- Improving the environment, public health and safety by establishing environmental performance of these novel and advanced biomass technologies for application in the region.

Proposed Outcomes:

1. Identify sites, resources, and scales of biomass power generation that might be developed over the near and long term.
2. Initiate industry collaborations for concept evaluation.

Project Status:

Kickoff meeting was held in 2002. CPR was held January 2004 with favorable replies from independent outside experts. Project is on-going.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 1.2 Photovoltaic Markets and Technologies

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 1.2 SEPA

Project Amount: \$316,376

Match Funding: \$0

Contract Project Manager: Stephen L. Hester, 202-457-0868

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, 916-654-4412

Project Description:

Use national TEAM-UP and PV industry technical and market knowledge to assess PV project goals and plans. Analyze and recommend the next phase of commercialization for energy service providers like SMUD that have established a successful solar energy market position in their region with significant customer interest in solar energy.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by obtaining the best technical and market input to the planning and setting of initial goals of PV projects in this program.
- Improving electricity reliability, quality, and sufficiency by developing the next options for solar energy market expansion in the SMUD region.

Proposed Outcome:

1. The overall goal is to have this CEC program benefit from the \$75 million TEAM-UP business model and hardware deployment program funded by the U.S. Department of Energy.

Project Status:

Project is on-going. A group of industry experts have been convened from the SEPA community and have held Task Force meetings addressing project specific activities. CPR was held January 2004 with direction from independent outside experts to complete draft reports by March 15th of 2004.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 1.3 Utility System Capacity and Customer Demand Value of PV - NREL

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 1.3 NREL Values

Project Amount: This project is a high level collaboration between federal and state agencies, and is not receiving any PIER funding.

Match Funding: Total Match

Contract Project Manager: Christy Herig, 303-384-6546

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, 916-654-4412

Project Description:

Photovoltaic systems have load profiles that are driven by available sunlight. The summer peak-period load profiles in Sacramento also track available sunlight and peak outdoor temperatures, although the peak is shifted about two hours into the evening by thermal lag and residential air conditioning. The National Renewable Energy Laboratory has looked at the California effective load carrying capacity (ELCC) for California's utility system as well as several types of customers. The ELCC for California is one of the highest, averaging 60%- 70%. Recent studies have shown that controlling building loads can improve this ELCC to 95%. However, current rate structures do not adequately reward building owners this type of load control. Similarly, current rate structures do not reward the owners of PV systems who orient their PV arrays westward to match the SMUD system peak. A potentially high value of either PV or advanced building control is not realized.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by using geosynchronous orbiting earth satellite (GOES) satellite data, verified by electric meter data, to determine the potential peak and capacity value of PV. Implementing findings of value into SMUD's accounting system, rates office, and business office.
- Improving the environment, public health and safety by assuming PV installations for various types of customers and analyze the potential benefits from both load factor and power factor manipulation.

Proposed Outcomes:

1. Analyze:
 1. PVs unquantified benefits.
 2. PVs match to utility peak.
 3. The benefits of orienting PV arrays to match PV output with utility demand peaks.
2. Beta test the solar load controller developed by the State University of NY.

Project Status:

Project is finished, with no costs to the state. Multiple reports and presentations to SMUD decision-makers have brought awareness of the value of PV to SMUD, including the Director, Jan Shori. It is envisioned that these values will be implemented in the SMUD rates and billing departments. A public report is available at the website: www.smud.org/pier/projects/pv1_3.html.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 1.4 Performance Indexing of PV Systems

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 1.4 PV Performance

Project Amount: \$ 250,000

Contract Project Manager: Sandia National Labs Andrew Rosenthal, 505-646-1323

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, 916-654-4412

Project Description:

Develop and implement on SMUD's centralized data base systems an automated monthly PI determination for each PV system interconnected to SMUD's grid based on system meter readings, and daily weather data. An exception report showing non-operating and under-operating systems will be automatically generated once each billing cycle. A year of trial operation and improvement will follow initial implementation.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by forming a reliable basis for calculating total hourly PV generation.
- Improving the environment, public health and safety by providing comprehensive and current information on operating health of each grid interconnected PV system.

Proposed Outcome:

1. A monthly exception report identifying non- and under-performing systems. A database available to SMUD staff showing health of any queried system for use with customer comments and concerns.

Project Status:

Sandia National Labs has decided to perform this project for no cost. The original funds have been freed to address inadequacies in other project tasks per the programmatic contract. A CPR was held in 2003 with favorable replies from independent outside experts. Over 800 SMUD PV systems are being analyzed using a database of information on the systems.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 1.5 Assessment of Worst-Case Weather Conditions

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 1.5 Worst Case Weather

Project Amount: \$27,000

Contract Project Manager: RWL Analytics of Sonoma CA, Eric Swan, 707-939-8823

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, 916-654-4412

Project Description:

Historical weather records will be analyzed to determine worst-case weather conditions for photovoltaic systems and air-conditioning systems. For PV systems, cloudiness from storms and fog will be examined. For cooling systems, a combination of maximum air temperature and humidity will be examined.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by developing data that will ultimately make it possible for PV to be used in mission-critical applications without being connected to the grid.
- Improving electricity reliability, quality, and sufficiency by developing weather data that can be used to determine the impact of winter weather on the performance of mission-critical PV systems, such as: traffic signals, transportation-related signage, retail signage, rural signage, streetlights, and parking lot lights.

Proposed Outcomes:

1. Develop data that will make it possible to correctly size and evaluate renewable-based air-conditioning equipment.
2. Develop weather data that can be used to determine the impact of summer weather on the sizing and performance of air-conditioning equipment of various types, including conventional and renewable.

Project Status:

RLW Analytics was awarded, by competitive bid process, to perform the project tasks. A CPR was held in 2003 with favorable replies from independent outside experts.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Emphasis Area 2: Increasing Affordability by Improving Existing Facilities

Project 2.1 Accelerated Anaerobic Composting for Energy Generation – Yolo County Landfill

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 2.1 Yolo Bioreactor

Project Amount: \$1,154,250

Match Funding: \$2,753,000

Contract Project Manager: Ramin Yazdani, 530-666-8848

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Zhiqin Zhang, 916-654-4063

Project Description:

This project is to provide technical and economics data and solution to the identified permitting condition that pose constraint in the advancement of this technology into the commercialization phase. This will be accomplished through resolving technical issues, regulatory constraints, and demonstrating the environmental and economic benefits of this technology.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by documenting the capital and operations cost of a full-scale bioreactor and determine the economic viability of it commercialization.
- Improving the environment, public health and safety by acceleration of waste decomposition and leachate treatment to accomplish rapid completion of composting, stabilization and generation of methane to the maximum practical yield.

Proposed Outcomes:

At project completion substantial technical and economics data will be available to the stakeholders, EPA, and State of California regulatory agencies. This will lead to the acceptance and commercialization of this technology throughout the state. As a result of this demonstration project and acceptance of the Bioreactor Landfilling concept by EPA, and the state, many other public and private landfill owners and operators will be able to implement this technology at other sites. The technology is expected to improve the economics of landfill gas to electricity and yield more renewable landfill gas and provide many environmental benefits for nearly all regions in the United States.

Project Status:

The project is currently on schedule and within the budget. Two Critical Project Reviews have obtained positive results from independent, external, technical experts. Successes foreshadowed include earlier and more rapid generation of landfill gas, improved quality of leachate, and reduction of greenhouse gas emissions. Multiple site visits have confirmed the project's activities.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Emphasis Area 3: Expanding Affordability and Diversity Using Renewable Distributed Technologies

Project 3.1 Laminate & Batten Roofing System

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 3.1 USSC PV Roofing

Project Amount: \$1,508,425

Match Funding: \$1,819,061

Contract Project Manager: Dr. Subhendu Guha, 248-475-0100

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, 916-654-4412

Project Description:

UNI-SOLAR will develop an inexpensive, easy and quick to install building integrated photovoltaic roofing system (PV Roof or PVR) which can be applied to any new or existing roof that has a plywood deck, particle board deck or any other type of solid, continuous under-structure. No comparable product exists at this time. The roofing material will be UNI-SOLAR's triple-junction thin-film amorphous product. The laminate and batten PV Roof will be researched and developed using the following process: The necessary hardware will be designed and tested. A new packaging and product-delivery system will be researched and developed. A UL listing will be procured. An initial demonstration phase of five projects will be completed and the projects will be monitored. Other demonstration projects will also be developed but they will not be monitored as part of this project. Installation and operation manuals and videos will be developed, as will a contractor training program.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by creating a low cost, dual function photovoltaics roofing using UNI-SOLAR large area thin film technology.
- Improving the environment, public health and safety by providing Class A fire rating and UL listing on all UNI-SOLAR building-integrated photovoltaic (BIPV) products. Developing manuals, videos and training program for designers, installers and users.

Proposed Outcomes:

Accommodate the widest range of residential and light commercial roofs. Develop fast, easy installation methods. Build an automated laminating/finishing facility to satisfy demand.

Project Status:

Project is near completion with major successes to date. Shipping and installation costs have been reduced with the development of an inexpensive reusable spool of laminates. Time-consuming junction boxes have been replaced by quick connects, potted to top or bottom of laminates. Innovative batten enables laminates to be the weather skin of a roof, thus providing additional value from this truly building integrated photovoltaic product. Multiple field trials and demonstration projects are confirming the products reduced costs and increased value. A demonstration was performed at the SMUD Hedge substation showing dozen's of solar experts the ease at which this product can be installed, and is the roof. The manufacturing sales team is investigating marketing channels and getting all product information ready for an announcement on availability. It is expected that this project costs the state only 1/3 the original budget, due to a reduction in expectation to manufacture the product in California. This project can help address the current administration's interest in getting photovoltaics into new home construction.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 3.2 BIPV Mounting Approaches for New Construction

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 3.2 Schott BIPV

Project Amount: \$99,180

Contract Project Manager: Miles Russell, 781-684-6102

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, 916-654-4412

Project Description:

Schott Applied Power Corp. (SAPC) will develop and document BIPV mounting approaches for new building construction. In conjunction with SMUD, SAPC will select a specific range of applications and develop specific mounting approaches for the building industry. SAPC will then develop information to be used by architects and designers.

This Project supports the PIER Program objective of:

- Improving energy cost/value of California's electricity by creating information such as drawings and specifications that can be used by architects, designers and engineers to promote the incorporation of BIPV in new construction.
- Improving the environment, public health and safety by identifying focus areas and review the functional requirements for selected BIPV mounting approaches.

Proposed Outcomes:

1. Greater options in BIPV mounting techniques for California architects and builders.
2. Greater awareness and adoption of PV practices by architects and builders.
3. Reduced cost of installation.
4. Increased use of BIPV in new construction.

Project Status:

Project started activities in 2003, after project #3.4 completed. A mock-up of a residential roof is being constructed at the RWE-Schott Solar headquarters in Rocklin, just outside of SMUD. CPR was held 2003 with favorable replies from independent outside experts. Builders are anxious to visit the headquarters prototype and explore usage in their developments. This project can help address the current administration's interest in getting photovoltaics into new home construction.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 3.3 Mainstreaming PV for Residential Roofs

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 3.3 Residential PowerLight

Project Amount: \$1,500,000

Match Funding: \$2,038,232

Contract Project Manager: Thomas Dinwoodie, 510-540-0550

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, 916-654-4412

Project Description:

PowerLight will develop a new residential PV roofing product, designed for both retrofit and BIPV applications, which meets the CEC goal of affordability. The product is a system of roof tiles with and without PV, with thermal insulating properties which significantly decrease house-cooling loads through a novel, strictly passive, means of roof deck temperature reduction and lowered attic dew points. The product will have a 50-year design life and will increase roof durability. Under this subcontract, PowerLight will carry out advanced design development, improving on first-generation prototypes, building and testing advanced prototypes, and using focus groups for product evaluation. A full-scale demonstration system will be installed and monitored for thermal and electrical performance. Requirements for certifications and code compliance will be fulfilled. A plan for high volume manufacturing will be completed.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by developing a market-ready product that improves upon existing residential PV roofing products in terms of cost, ease and speed of installation, and electrical and thermal performance.
- Improving the environment, public health and safety by adding insulation value of R-50 to the rooftop (both PV and non-PV tiles, which go around the PV array and on the roof's north slope.
- Maintain PV cell temperatures at relatively cool, "rack-mount" levels, unlike other direct-mounted, building-integrated PV products, resulting in 10-18% higher module output.
- Be certified by Underwriters Laboratories (UL), International Conference of Building Officials (ICBO), and Institute of Electrical and Electronics Engineers (IEEE).

Proposed Outcomes:

1. Be designed for retrofit and building-integrated applications, both waterproof assemblies.
2. Be simple to install using traditional roofing practices, including waterproofing, and edge, ridge, and eave details. PV modules snap into a pre-engineered mounting system, easily done by one person on a sloped roof surface.
3. Integrate electrical wiring and interconnection into the mounting system, which will be accessible after installation.
4. Have electricity and thermal performance that could obtain recognition by CEC Title 24.
5. Have a 50-year design life and increases roof durability.

Project Status:

Project is underway. First phase of the project is completed with a roll out of PowerLight's new product at the Utility Photovoltaic Experiences conference in Austin Texas, November 2002. This new product is lightweight, ships easier, and can help reflect more light onto modules than previous solutions. It is a flat or sloped roof product. The project continues to develop the more challenging version for sloped residential roofs. CPR was held in April 2003 with favorable views from independent outside experts. This project can help address the current administration's interest in photovoltaics for new home construction.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 3.4 Flat Roof Mounting Approaches

Contract #: 500-00-034

Contractor: SMUD Programmatic-3.4 Schott Flat Roofs

Project Amount: \$ 100,450

Match Funding: \$230,000

Contract Project Manager: Miles Russell, 781-684-6102

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, (916) 654-4412

Project Description:

Schott Applied Power Corp. (SAPC) will develop a mounting approach for flat roof top installations. SAPC will meet with SMUD to determine necessary design constraints. Next, SAPC will develop and prototype a design. A manufacturing review will be completed after the prototypes have been fabricated. A demonstration array will be constructed to illustrate the completed design.

This Project supports the PIER Program objective of:

- Improving energy cost/value of California's electricity by developing modules to easily be mounted on a flat rooftop. The ideal design would eliminate the use of additional ballast materials, or numerous penetrations, although engineering and adherence to appropriate codes must temper these factors.
- Improving electricity reliability, quality, and sufficiency by reviewing the customer requirements for mounting approaches on buildings with flat roofs. Developing and prototyping designs that meet those approaches.

Proposed Outcomes:

The results of this work should facilitate the use of PV technologies in California. The primary proposed outcomes of this work are anticipated to be:

- Greater choice for purchasers of PV systems.
- Reduced cost of installation.
- Increased flexibility for deploying PV systems.

Project Status:

Project is completed with a commercialized product in the market place. PIER has been recognized as supporting the development of this product in the brochure. This product brings competitive value added solution to the flat roof, commercial market. It requires no roof penetrations, has a taller roof jack with dynamic features, is lightweight, reduction costs, and is more flexible to roof obstacles.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 3.5 Optimization of Residential PV Systems

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 3.5 AstroPower Concrete

Project Amount: \$1,127,000

Match Funding: \$1,197,000

Contract Project Manager: Marc Roper, (925) 288-0400

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, (916) 654-4412

Project Description:

AstroPower will research and develop components and an integrated system design for its packaged residential solar electric power systems optimized for the California market. To accomplish this, AstroPower will research and develop an advanced:

- PV module/laminate product and associated mounting and wiring system.
- Power Conditioning Unit (PCU) for grid-connected PV systems.
- Low-cost PV system meter appropriate for the new module/laminate, PCU, and system design configuration.

Astro Power will integrate the advanced module/laminate, PCU, and meter elements into a line of packaged residential PV systems. Through these development activities, Astro Power will improve performance, aesthetics, functionality, usability, and reduce consumer cost by approximately 20%.

This Project supports the PIER Program objective of:

- Improving energy cost/value of California's electricity by researching and developing an advanced, low-cost PV monitoring system that displays real-time "solar fraction" which will:
 - display the monetary value of the solar electricity the system has generated. Indicating when the solar electric system is selling electricity to the utility. Displaying the status of the battery bank (if applicable). D
 - provide feedback indicating acceptable operation. P
 - record operating data and transmitting data to a remote location for viewing on the Internet if cost effective. R
 - improve electricity reliability, quality, and sufficiency by researching and developing a Power Conditioning Unit (PCU) that: I
 - Track the array maximum power point.
 - Invert DC to AC power at no less than 93% efficiency.
 - Operates through a wide range of DC input voltages to enable single-string arrays of various sizes.
 - Incorporating all AC and DC switching and protective devices and designing flexibility, such as array size and battery usage.

Proposed Outcomes:

Research and develop a PV module/laminate product and associated mounting and wiring system that:

1. Will be accepted by mainstream consumer markets.
2. Reduces or eliminates penetrations of the roofing membrane (flushed “feet”) for new construction.
3. Functions as part of a weatherproofing system, though not necessarily a “Building Integrated PV” product.
4. Presents an appearance that is more consistent with conventional roofing, and minimizes or eliminates the visibility of mounting or wiring hardware from the ground.
5. Works with the majority of the roofing products predominant in sloped-roof residential construction in California, including Spanish tile and concrete tile.
6. Eliminates the need for inter-module hardwiring and conduit on the roof.

Project Status:

Project has produced a successful commercialized product for residential roofing. AstroPower has developed a photovoltaic module that works with concrete tile roofing systems found on California homes the product is called Gecko. AstroPower has recently announced bankruptcy, with GE Energy poised to competitively bid for the corporate assets. GE Energy could have positive ramifications for the future of Gecko and associated project related advancements.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 3.6 Remote Dispatch & PV Irrigation

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 3.6 PV Irrigation.

Project Amount: \$77,000

Match Funding: \$150,000

Contract Project Manager: World Water Corporation, Quentin T. Kelly, 609-818-0700

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, (916) 654-4412

Project Description:

Designs for two PV irrigation projects will be completed: one grid-connected and one stand-alone. Both designs will be implemented in demonstration projects. The demonstration projects will be monitored and evaluated. The demonstration projects will be used to test the PV-based spot market for electricity sales. Many agricultural wells in Sacramento County are fairly large, so the PV systems may be large enough and produce sufficient electricity, if aggregated, to be of interest as spot-market generators.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by evaluating irrigation requirements with respect to pumping horsepower, monthly hours of operation and preferred time of irrigation.
- Improving electricity reliability, quality, and sufficiency by developing PV-powered irrigation systems designs and demonstration projects.

Proposed Outcomes:

1. Create the basis for a PV agriculture irrigation program in the Sacramento area.
2. Test market for remote dispatch of PV systems in agricultural applications.
3. Evaluate the need for battery storage for a variety of situations.
4. Design systems with optimized PV and battery sizing.
5. Implement two demonstration projects – one grid connected and one grid-independent.

Project Status:

The bidding process has identified World Water Corporation as the technical contractor. Project is currently underway.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 3.7 PV and Evaporative Cooling

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 3.7 PV Evaporative cooling

Project Amount: \$ 50,000

Match Funding: \$ 30,000

Contract Project Manager: Davis Energy Group, Dick Bourne, 530-753-1100

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, (916) 654-4412

Project Description:

PV will be tested for use with locally manufactured two-stage evaporative cooling units in residential demonstration projects. Two types of demonstration projects will be implemented:

- (1) PV delivering 115VAC power to a home with a two-stage unit.
- (2) PV delivering 48VDC directly to a unit modified to accept DC power and 115VAC to the home or grid when there is no demand for cooling. The installations will be monitored and the results presented in a final report.

This Project supports the PIER Program objective of:

- Improving energy cost/value of California's electricity by laying the groundwork for creating a new market for PV and begin to address air conditioning as a peak-load driver.
- Providing greater choices for California consumers by monitoring and evaluating the demonstration projects. Building a DC-operated indirect/direct evaporative cooling unit.

Proposed Outcomes:

Complete a demonstration project with 115VAC PV and a 115VAC evaporative cooling unit. Complete a demonstration project with 115VAC/48VDC PV and a 48VDC evaporative cooling unit.

Project Status:

The bidding process has identified Davis Energy Group as technical contractor. Project is currently underway.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 3.8 Solar Dish Concentrating with Stirling Engine

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 3.8 SAIC Solar Dish

Project Amount: \$1,301,000

Match Funding: \$190,000

Contract Project Manager: Rob Taylor, (858) 826-9124

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, (916) 654-4412

Project Description:

SAIC is proposing to develop a 20-25 kW solar dish/Stirling system and design a solar dish/photovoltaic system. This work expands upon previous SAIC dish/PV programs and the results from other design work.

This Project supports the PIER Program objectives of:

- Providing greater choices for California consumers by utilizing a solar dish/Stirling system.
- Improving electricity reliability, quality, and sufficiency by fabricating fixed focal length mirror facets for a solar dish/PV system and design the integration of the SAIC solar concentrating dish with a 20 kW PV receiver.

Proposed Outcomes:

Integrate the proven SAIC solar concentrating dish with the 25 kW STM Beta Stirling engine, achieve 22% solar conversion efficiency with 90% availability. Further the reliability and experience in working with both dish/Stirling and dish/PV systems.

Project Status:

The dish/Stirling system has shown better performance and reliability in operation than any previously operating system. The opportunity exists to continue research on the dish/Stirling's operating performance. NREL continues its investigation into the dish/PV system. Due to the immaturity of the technology the project has implemented a critical decision, with the help of outside technical experts, not to continue with a demonstration in the Sacramento area.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Emphasis Area 4: Developing Renewable Technologies for Tomorrow's Electricity System

Project 4.1 Non-Vacuum Thin-Film CIGs Modules (SMUD/ReGen)

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 4.1 Non Vacuum CIGS

Project Amount: \$470,812

Match Funding: \$496,000

Contract Project Manager: Chris Eberspacher, (805) 987-7258

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, (916) 654-4412

Project Description:

The purpose of this project is to explore a simple, low-cost alternative based on non-vacuum processes. The PV industry is currently dominated by solar cells fabricated from wafers of high purity silicon. The underlying cost of semiconductor wafers constrains the cost reduction potential of wafer-based PV technologies. One of the most promising strategies for lowering the cost of PV is the use of thin-film technologies in which thin coatings of PV materials are deposited on inexpensive substrates like window glass. However, the vacuum techniques typically used to deposit PV thin films are complex and capital intensive. The basic concept is to prepare fine powders of precursors materials, deposit thin layers of particulate materials using simple non-vacuum techniques, and convert the layers into high-quality PV films by reactive sintering. Reactive sintering techniques facilitate film densification at low temperatures. The figure (1) below illustrates the basic technique for forming thin film.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by demonstrating that low-cost non-vacuum processing can yield large and efficient PV modules.
- Improving electricity reliability, quality, and sufficiency by developing the equipment and processing parameters necessary to fabricate multi-cell modules using particles-based non-vacuum processes.

Proposed Outcomes:

Fabricate efficient thin-film PV modules using particles-based non-vacuum processes. Extend innovative new techniques to fabrication of larger-area modules. This project is a longer-term research project, which supports the PIER Program objectives of developing a new generation of low-cost renewable technologies for tomorrow's electricity system. Such cost reductions will significantly accelerate the commercialization of thin-film CIGS PV technology and deliver to California electricity ratepayers the benefits of low-cost, clean energy from renewable solar power.

Project Status:

Small-area modules (1" x 1") were fabricated and tested in 2002. In December 2003, Unisun measured 5% efficiency for 10 cm x 10 cm 13-cell monolithic integrated module fabricated from CuInGaSe₂ processed using non-vacuum method. This is an important milestone in thin film research and development activities. The project is demonstrating small, to larger scale higher efficiency improvements.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 4.2 Maximum Power Point Tracker Inverter Development

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 4.2 SMA Inverter

Project Amount: \$708,900

Match Funding: \$120,000

Contract Project Manager: John Berdner, (530)-273-4895

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, (916) 654-4412

Project Description:

Develop and field test a PV inverter incorporating both maximum power point tracking and dispatchable energy storage functions.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by developing low cost grid feeding inverter incorporating both maximum power point tracking functions and backup power capabilities.
- Providing greater choices for California consumers by developing a remote dispatchability capability for renewable power systems. Demonstrating in field trials to verify the effectiveness of customer sited renewable power systems as an energy management tool.

Proposed Outcomes:

The outcome of the proposed project will be the availability of a low cost energy conversion unit that maximizes the value of renewable energy systems with energy storage. This product will better meet the needs of the California consumer and thereby accelerate the widespread adoption of renewable energy systems in the State. A secondary outcome will be the demonstration of the economic value of dispatchable energy storage functions in renewable energy systems.

Project Status:

Project is currently underway. Beta test units were reviewed by staff at the Grass Valley California facilities. This project can help add electrical storage value to the current administration's interest in photovoltaics for new home construction.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 4.3: Hybrid PV/Lighting System (SMUD / ReGen)

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 4.3 ORNL Hybrid Lighting

Project Amount: \$100,000

Match Funding: \$230,000

Contract Project Manager: Jeff D. Muhs, (865)946-1281

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Hassan Mohammed, (916) 651-9855

Project Description:

The purpose of the project is to demonstrate for the first time (in a commercial building setting) the technical feasibility of hybrid lighting systems.

Hybrid lighting is a revolutionary approach to lighting that integrates light from natural and electric sources. Hybrid lighting systems collect and distribute the visible portion of sunlight using large-core optical fibers and combine it with electrically generated light in existing light fixtures. The natural and electric light sources work in unison to light commercial buildings where lighting represents the single largest consumer of electricity. The remaining “invisible” energy in the sunlight, mostly infrared radiation, is directed to a concentrating thermo-photovoltaic cell that very efficiently converts infrared radiation into electricity. The resulting electric power can be directed to other uses in the building.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California’s electricity by demonstrating the technical feasibility of a novel solar concentrator that splits the solar spectrum, illuminating building interiors using the visible portion and generating electricity from the infrared portion via low-cost concentrating thermophotovoltaic solar cells.
- Improving the environment, public health and safety by addressing building code and permitting issues in a commercial setting and developing a system-level building integration strategy.

Proposed Outcomes:

This project supports the PIER Program objectives of developing systems for tomorrow's energy needs that are highly responsive to commercial demand, supply quality-of-life health/productivity benefits, fully-integrated with customer appliances (electric lighting) and offset peak demand. The demonstration promises to more than double the overall efficiency, affordability and market penetration of solar energy leading to smart, super-efficient, super-clean renewables having combined generation and displacement efficiencies greater than 70 percent.

Project Status:

This is a demonstration project, scheduled for installation in 2004.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 4.4 Slat-Array Concentrator Development (SMUD/ReGen)

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 4.4 SSV Slat Array Solar

Project Amount: \$347,270

Contract Project Manager: Dr. Sergy Vasylyev, (916) 381-1665

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Joseph McCabe, (916) 654-4412

Project Description:

The purpose of this project is to develop and test a slat-array concentrating photovoltaic (CPV) prototype module with increased efficiency and reduced cost and operation.

The concentrating photovoltaic (CPV) is an emerging technology which appears to be the least expensive and most efficient of all photovoltaic technologies due to substituting a large fraction of expensive flat-plate PV panels with less expensive concentrators supplied by tracking systems. To fully exploit the advantages of CPV's and achieve relatively high concentration ratios, a number of approaches based on Fresnel lenses and parabolic mirrors have been devised.

However, none of the existing solar concentrators provides desired operation at a reasonable cost, thus limiting the acceptance of CPV technology.

This project promises a unique opportunity to naturally combine the robustness and high efficiency of the reflective optics and design conveniences of the Fresnel lens technology in a single and inexpensive CPV device based on a novel slat-type concentrator concept. The slat-array module developed in this project will consist of specially designed asymmetric linear concentrator and an array of concentrator silicon solar cells electrically interconnected and mounted on a single wafer. The concentrator will consist of a set of narrow reflective slats reflecting the solar energy to the line-arranged cells. Each reflective slat will have a specific concave profile in the cross section to provide light focusing capability.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by developing and test a slat-array concentrating photovoltaic (CPV) prototype module with increased efficiency and reduced cost and operation.
- Improving electricity reliability, quality, and sufficiency by significantly improving the practicability of reflective optics by introducing the lens-like slat-array concentrator concept and developing it for uniform illumination of photovoltaic cells at moderate sunlight concentration.

Proposed Outcome:

This project is a longer-term research project which supports the PIER Program objectives of developing a new generation of low-cost renewable technologies for tomorrow's electricity system.

Project Status:

To date, two CPR's have been held with favorable replies from independent outside experts. A small prototype has been demonstrated, and a larger 500 watt system is currently being produced.

Continued: SMUD/CEC Renewable Generation RD&D Program (ReGen R&D)

Project 4.5: Distributed Generation Drivetrain for MW Turbines

Contract #: 500-00-034

Contractor: SMUD Programmatic- Project # 4.5 Dehlsen Geartrain

Project Amount: \$1,299,000

Match Funding: \$836,000

Contract Project Manager: Dr. Amir Mikhail, 805-690-3275

Commission Project Manager: Elaine Sison-Lebrilla, P.E / Joseph McCabe, 916-654-4412

Commission Technical Lead: Dora Yen, (916) 653-4128

Project Description:

As wind turbines continue to increase in capacity and rotor diameter, gearbox torque loads and component costs increase accordingly. New designs are needed for reducing the cost and increasing the reliability of these the large systems. The Distributed Generation Drivetrain (DGD) technology proposes patent-pending solutions to address the exponentially increasing torque loads on large utility-scale turbine drive trains and at the same time include improvements that decrease system weight and costs. The tremendous load reductions are obtained by splitting the torque along multiple paths at the low speed end of the gearbox between small, parallel gearboxes and multiple off the shelf generators. Extreme loads on individual gear tooth are thereby reduced. These improvements reduce gear teeth wear, gearbox cost and weight, installation requirements, and warranty risks. The focus of the project is to design, construct and test a commercial-scale (1.5MW) DGD along with an integrated controller. The weight savings and torque reduction achieved over current monolithic generator systems will measure project successes.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by:
 - Engineering a commercially-viable gearbox to either enable cost saving retrofits of existing turbines or provide the drive train for a new lighter weight, low cost turbine design.
 - Providing full cost-scaling and design tradeoff data for a compact multi-generator gearbox design.
 - Providing data to determine the optimal number of generators to use for each turbine.
- Improving electricity reliability, quality, and sufficiency by constructing the DGD system, integrating the DGD controller with a new non-patent infringing variable speed capability and performing load testing of the DGD system on the NREL dynamometer test stand.
- Increasing reliability by reducing gearbox failure by decreasing gear tooth stress, and allowing turbine operation even if one or more generators fails.

Proposed Outcomes:

The 1.5MW single stage DGD is projected to cost under \$100,000 compared to \$170,000 for present turbine gearboxes. The innovative gearbox design allows for either a retrofit of existing turbines or provides the drivetrain for a new low-cost turbine design. Through gearing and multiple path load division, the highest gear tooth stresses (found in the first gearbox stage) are substantially reduced resulting in an overall gearbox drivetrain weight and volume reductions. The significant size and weight savings and use of conventional generators provide as much as 0.4¢/kWh cost of energy reductions for wind turbine generators or 10% COE reductions.

Benefits to California include a cost-competitive and reliable turbine fleet, lower COE and environmental and economic benefits of using diversified renewable generation technologies.

Project Status:

Load analysis and design tradeoffs have lead to a optimal gearbox layout and 8 generator configuration. The preliminary DGD design was finalized and a gearbox manufactured. Assembly and testing at NREL has been ongoing for the majority of 2003. SMUD envisions a power purchase agreement being developed with the next generation DGD design, a 2.5 MW turbine, located at the SMUD Solano Wind Farm.

Strategic Value Analysis: GIS Development

Contract #: 500-00-030

Contractor: California Department of Forestry

Contract Amount: \$280,000

Contractor Project Manager: Dean Cromwell (916) 227-2667

Commission Contract Manager: Prab Sethi (916) 654-4509

Status: Active

Project Description:

The PIER Renewables area is investigating the ability of renewable resources to help make California's electricity system more reliable, affordable, diverse and cleaner. Part of that effort involves assessing the types and magnitudes of problems that may be encountered in the state's electricity system in the future. Another part of that effort involves assessing the amounts, locations and characteristics of renewable resources that could possibly be used to help resolve the identified electricity system problems. Due to the large amount of data and complexity nature of the issues being addressed, the assessments will be conducted using Geographical Information Systems (GIS). The purpose of this contract is to build off of an existing GIS developed and operated by the California Department of Forestry (CDF) to help conduct the assessments. To accomplish this goal, CDF will do the following:

- Analyze existing spatial information related to energy use, environmental and demographic characteristics of sub-regions within the state.
- Create required data layers on available renewable energy resources.
- Use data on problem areas within California's electricity system developed by another contract (500-00-031).

As a result, this contract will identify areas where renewable DG systems can potentially help address electricity reliability, congestion and power quality problems. At the same time, this contract will provide public benefits such as improving air quality, preventing wildfires in high-risk areas, and increasing employment in economically stressed areas of the state.

This project supports the PIER Program objective of:

- Improving the reliability/quality of California's electricity by identifying where renewable distributed generation systems can be located to help alleviate transmission and distribution capacity and congestion problems in the state.

Proposed Outcomes:

1. Collect data sets necessary to create thematic layers on renewable energy resources within California, layers on detailed demographic, environmental, and energy use information, and layers that incorporate the results from the McNeil Technologies (500-00-031) power flow analysis.
2. Construct thematic layers and develop methods for running iterative scenarios that help determine optimal locations for renewable generating systems that provide strategic benefit to California's electricity system as well as high public benefits that extend beyond impacts to the electricity system.
3. Develop a windows based program (or equivalent process) that enables staff in the PIER Renewables program to remotely access the GIS information, run different and new scenarios based on new data, and collect the associated results.

Renewable Energy Technologies

4. Assist in establishing at least two case studies that provide representative and site-specific analyses on the use of renewable distributed generation systems to effectively and affordably address California electricity system problems.
5. Provide a written report and GIS-based maps depicting the key results obtained from the various GIS scenarios, and the two case studies. The key results will include identification of the optimal locations where renewable generation systems can possibly provide strategic benefit to California's electricity system as well as high public benefits.

Project Status:

After passage of the state's Renewable Portfolio Standard and the Energy Action Plan goals for renewables, the PIER Renewables group was asked to have the work on this project help identify impacts to the transmission system and the ability to accelerate RPS goals. Consequently, this meant an additional workload and delays in the original schedule. However, the contractor has provided over fifty percent of the work products on the needed GIS model and mapping efforts.

Strategic Value Analysis: Power Flow Simulations and Development of Renewable RD&D Performance Goals

Contract #: 500-00-031

Contractor: McNeil Technologies

Subcontractors: Davis Power Consulting

Contract Amount: \$1,261,980

Contractor Project Manager: Scott Haase (303) 980-1969

Commission Contract Manager: Prab Sethi (916) 654-4509

Status: Active

Project Description:

The PIER Renewables area is investigating the ability of renewable resources to help make California's electricity system more reliable, affordable, diverse and cleaner. Part of that effort involves assessing the types and magnitudes of problems that may be encountered in the state's electricity system in the future. Another part of that effort involves assessing the amounts, locations and characteristics of renewable resources that could possibly be used to help resolve the identified electricity system problems. Due to the large amount of data and the complex nature of the issues being addressed, the assessments will be conducted using power flow models and Geographical Information Systems (GIS). The purpose of this contract is to simulate the condition of California's electricity system in the future to identify possible capacity, congestion or reliability problems that could potentially be addressed using renewable energy resources. The work will involve identifying the locations and magnitude of the potential electricity system problems, the amounts and power generation characteristics of renewable energy sources that could possibly help address the problems, and the impacts of injecting renewable electricity generation into the problem areas. Moreover, in combination with the GIS work under a separate contract (Department of Forestry: 500-00-030), the results will be used to assess possible economic and environmental benefits resulting from deployment of renewables to help address the electricity problems. Lastly, the combined results will be used to develop economic, technical and environmental research and development targets for future renewable energy technologies.

This project supports the PIER Program objective of:

- Improving the reliability/quality of California's electrical system by identifying the locations and characteristics that will best enable renewable electricity systems help alleviate electricity capacity, reliability and congestion problems in the state.

Proposed Outcomes:

- Identify and characterize generation and transmission and distribution (T&D) problems confronting California's electricity system over the next 5 and 10 years using power flow models calibrated to California's electricity system and based on various demand scenarios.
- Determine the performance characteristics of generation, distribution, transmission and substation upgrades or expansions needed to effectively address electricity system problems over the next 5 and 10 years as identified in the power flow models.
- Identify locations within California's electricity system where sufficient renewable generation supplies exist to effectively address electricity system "hot spots" as identified in the power flow models and the GIS results obtained from an associated contract.
- Establish at least 2 case studies that provide representative and site specific analyses on the use of renewable generation systems to effectively and affordably address

California's electricity system problems, while simultaneously providing other high public benefits.

- Specify PIER renewable energy research and development goals that act as targets for the required performance and cost characteristics that will enable advanced renewable generation systems to help address the problems facing California's electricity system.

Project Status:

- Work is progressing for developing datasets for power flow modeling of California's electricity system and power flow model simulations of California's hot spots.
- The McNeil Contract related to the Strategic Value Analysis was signed by the General Services on January 29, 2002.
- A kick off meeting was held on May 17, 2002 with McNeil Technologies and subcontractors to review scope of work and administrative items.
- Critical Project Review/project progress meeting have been held to review tasks 2.1 and 2.2 to discuss preliminary results of power flow modeling, and technology characterization.
- Task 2.1 – Power flow Modeling:
 - Data was compiled for summer peak power flows for 2003, 2005, 2007, 2010 and 2017. DPC has worked on simulation of hot spot, power flow modeling and analysis of wind and geothermal locations. Wind locations have been identified. Geothermal locations have also been identified. Similar work is continuing for the biomass and solar technologies.

Task 2.2 – Technology Characterization and Targets

McNeil has submitted a draft copy of the Strategic Value Analysis of Renewable Power Technologies report. McNeil has also submitted preliminary economic models for wind, geothermal, solar and biomass technologies. Work is continuing to finalize this task.

Major Forthcoming Milestones/Concerns:

The project was going on a fast track so that the results could be used as input to RPS. However, a stop work order was issued during December 2003 because the contract amendment was not signed by DGS.

Work performed so far by McNeil and DPC is being reviewed. The remaining scope of work to be performed by each contractor will be assessed. Then, the contractors will be provided direction and priorities to proceed on this project.

This contract was amended to add \$531,980 for a total budget of \$1,261,980 so that renewable resources can be identified to address requirements of SB 1078 to provide 20 percent of the retail sales from renewable electricity resources by 2017.

The Flex-Microturbine for Landfill and Digester Gases

Contract #: PIR-02-004

Contractor: FlexEnergy, Inc.

Subcontractors: Capstone Turbine Corporation

Contract Amount: \$499,548

Match Amount: \$698,548

Contractor Project Manager: Edan Prabhu (949) 380-4899

Commission Contract Manager: Prab Sethi (916) 654-4509

Status: Active

Project Description:

The purpose of this project is to demonstrate the applicability of an advanced microturbine (i.e., the Flex-Microturbine) fueled by landfill gas and or digester gas, and which has extremely low emissions. In addition, the project will demonstrate the capability of the microturbine to use biogas fuels with energy contents as low as fifteen percent that of natural gas. A proof of concept prototype for the Flex-Microturbine has been successfully demonstrated and prototypes are being constructed and tested under this project. Prototype 1 will run on digester gas at a biogas project located at Cal Poly San Luis Obispo, and Prototype 3 on very low Btu landfill gas at the LA County Sanitation Districts' Puente Hills landfill. The Flex-Microturbine will run on gases with energy content from 15 to 300 Btu per standard cubic foot (scf) and also on high Btu gases. It will handle a high variability in gas energy content.

Testing to date indicates the microturbine produces virtually no NO_x (from 0.05 to 1.0 PPM or 0.0004 to 0.00075 lbs./MM Btu), and does not require a separate fuel compressor. Internal combustion engines require fuel of at least 400 Btu/scf and traditional microturbines require at least 300 Btu/scf. This project will demonstrate that it can overcome problems associated with gas impurities (high moisture, particulates, etc) and show that the Flex-Microturbine can be a long lasting, cost-effective electricity distributed generation (DG) technology using waste gases. The benefits include new DG power generation that can operate with peaking capability, waste gas reduction, greenhouse gas reductions, NO_x reductions and relieving grid congestion.

This project supports the PIER Program objectives of:

- Improving the energy cost/value and the reliability/quality of California's electricity by developing a coordinated set of advanced renewable energy technologies that together will help make renewables part of a more affordable diverse electricity system.
- Improving environmental and public health costs/risks from California's electricity system by developing clean renewable energy technologies that have no air polluting emissions.

Proposed Outcomes:

- Successful demonstration of Flex-Microturbine using landfill gas and digester gas with characteristic heating value of 50 to 300 Btu per cubic foot.
- Demonstration of catalyst life of at least three months.
- Successful demonstration of NO_x emissions level from 0.0004 to 0.00075 lbs./MM Btu (about 0.5 to 0.1 ppm in the exhaust).
- Achieve a cost goal of commercial Flex-Microturbine for electricity generation at about \$0.04 per kWh.

Project Status:

The funding for this project is conditional on successful performance of another FlexEnergy project, Contract Number 500-99-030. The performance results are expected to be available by July 2004, when it will be determined how to proceed with this project.

The Flex-Microturbine Uniquely Adapted to Low Pressure Biomass Gas

Contract #: 500-99-030

Contractor: FlexEnergy, Inc.

Subcontractors: Capstone Turbine Corporation : National Renewable Energy Laboratory (NREL) : University of California, Davis

Contract Amount: \$983,653

Match Amount: \$1,733,031

Contractor Project Manager: Edan Prabhu (949) 380-4899

Commission Contract Manager: Prab Sethi (916) 654-4509

Status: Active

Project Description:

The purpose of this project is to design, develop and demonstrate a microturbine (i.e., the Flex-Microturbine™) capable of generating very clean electricity while being powered by a variety of gaseous waste fuels. To date, gaseous waste fuels (i.e., biogas fuels) have been difficult to use for electricity generation due to their relatively low energy contents and high air pollution emissions. In turn, these problems have contributed to biogas projects being marginally economic. Among the biogas fuels to be demonstrated in the Flex-Microturbine™ include:

- Biogas generated from anaerobic digestion of livestock manure.
- Producer gas generated from thermal gasification of orchard and forest residues.
- Biogas from landfill gas recovery system.

This project is Phase II of small modular biomass (SMB) initiative co-funded by the National Renewable Energy Laboratory (NREL)/US Department of Energy (US DOE). In this Phase II, the Contractor will design, develop and demonstrate a proof of concept (POC) and three prototypes of Flex-Microturbine™. Prototype 1 will be fueled from biogas generated from anaerobic digestion of livestock manure. Prototype 2 will be fueled from producer gas generated from thermal gasification of orchard and forest residues. Prototype 3 will be fueled from landfill gas. Prototypes 1 and 2 are funded by PIER and co-funded by NREL/US DOE. Prototype 3 is funded by NREL/US DOE only and not part of the PIER project. Phases I and IA of SMB initiative are feasibility and preliminary design stages, respectively. Phases 1 and IA are completed and funded through NREL/US DOE.

This new Flex-Microturbine™ is intended to act as safe, reliable, clean, cost-competitive provider of renewable energy with particular value to California's deregulated electricity marketplace.

This project supports the PIER Program objectives of:

- Improving cost competitiveness of the biomass energy conversion technologies, and reducing costs of California's electricity.
- Improving environmental and public health costs/risk of California's electricity by mitigating air quality impacts and reducing environmental risks.
- Improving the reliability/quality of California's electricity by developing a new distributed generation technology.

Proposed Outcomes:

The technical objective of this project is to design, develop and demonstrate a Flex-Microturbine that can run on low pressure and low Btu gases from biogas generated from the anaerobic digestion of livestock manure, from producer gas generated by thermal gasification of orchard and forest residues, and biogas from landfill gas recovery system.

The economic objective of this project is to develop the Flex-Microturbine™ to provide cost competitive renewable energy in a deregulated electricity marketplace.

Specific technical performance objectives of this project are:

1. Proof-of-Concept (POC):

The following activities will demonstrate that a fuel and air mixture of 100 Btu/scf to 800 Btu/scf can be successfully and safely mixed and used to achieve combustion in a microturbine, using natural gas as the fuel. These activities will address three applications:

 1. Attain successful combustion for 4 hours for the specified mixtures.
 2. Measure emissions, including NO_x and hydrocarbons.
 3. Measure temperatures, pressures, output and other pertinent performance parameters.
2. For Prototype 1 (Digester Gas and Demonstration Unit).
 - Conduct shop tests as in POC.
 - Demonstrate safe startup and shutdown.
 - Demonstrate ability to accept fuel gas at less than 0.25 psig.
 - Operate for 7 days on digester gas.
 - Ammonia-free NO_x emissions below 9 PPM (15 %O₂).
 - Attain at least 25% gas-to-electricity efficiency (13,684 Btu/kWh, LHV).
 - Ability to load follow (operate at different loads, 20% to 80% capacity).
 - Ability to handle wide variation in fuel Btu content (200 to 800 Btu/scf).
3. For Prototype 2 (Wood Gasifier Prototype and Demonstration Unit).
 - Demonstrate capability to operate for at least 8 hours at a time for 5 days in a row.
 - Demonstrate ability to accept gas at below 0.25 psig.
 - Demonstrate safe startup and shutdown.
 - Demonstrate capability to run on gas with normal rated gasifier output (112 Btu/scf, 5 PPM tar, 5 PPM particulates).
 - Attain at least 25% gas-to-electricity efficiency (13,684 Btu/kWh, LHV).
 - Ability to handle gas Btu variations (with a minimum of 100 Btu/scf).
 - Ability to run on below normal gas quality (100 Btu/scf gas) for 8 hours.
 - Test ability to run three Flex-Microturbines running on one gasifier.
 - NO_x emissions below 9 PPM (@15 % O₂).
 - Particulate emissions below 0.02 lb./MWH.
4. For Prototype 3 (Landfill Gas Prototype and Demonstration Unit).
 - Demonstrate safe startup and shutdown.
 - Attain at least 25% gas-to-electricity efficiency (13,684Btu/kWh, LHV).
 - Demonstrate ability to accept gas at below 0.25 psig.
 - Operate continuously for 30 days.
 - NO_x emissions below 9 PPM (@15 % O₂).
 - PM10 Particulate emissions below 0.02 lb./MWH.
 - Demonstrate ability to run on gases as low as 100 Btu/scf for 24 hours.

The specific economic objectives of this project in mature commercial volumes are:

1. The Flex-Microturbine™ will be available for about \$400 a kW. This price assumes the global sales of microturbines over 10,000 a year.
2. In landfill gas applications, where the gas is already available in most landfills in the state, power will be produced for less than \$0.03 a kWh with a capacity factor of 90%.

3. The entire power plant, including a manure digester, will cost about \$800 a kW when about one hundred digesters are installed. Power will be produced from digester gas at about \$0.03 a kWh with a capacity factor of 90% without considering the benefit of energy and environmental credits
4. The portable wood gas power plant, including the gasifier, will be available for \$1000/kWh, in volumes of over one hundred a year. Power will be produced for less than \$0.05 a kWh.

Project Status:

The project kick-off meeting was held at the Capstone offices in Chatsworth, California on July 26, 2000. Work for the design and testing of the Prototypes 1 and 2 is in progress as shown below:

- Prototype 1 (Digester Gas):
 - The design for the prototype has been upgraded to accommodate significantly greater volume of needed catalyst.
 - Prototype 1 is being tested at Capstone's test facilities. The prototype has been run for more than 1400 hours to check life of catalyst. However, the control system is unstable, and need additional work for startup and transient control. A small amount of unburnt gases is bypassing the catalyst through leakage path in the microturbine.
 -
- he shop testing and field testing is far behind schedule.
- Prototype 2 (Wood Gasifier):
 - The design for Prototype 2 will be similar to Prototype 1.
 - A 15 kW gasifier has been delivered by the Community Power Corporation (CPC) to the Energy and Environmental Research Center (EERC) in Grand Forks, ND. CPC has supplied gas filters with 50% additional surface area to control filter clogging.
 - The testing is behind schedule because the microturbine has not been delivered to EERC.

The contract completion date is March 31, 2004. The microturbine assembly and testing has been affected due to loss of Capstone persons working on the Flex turbine. A critical project review meeting was held on January 7, 2004 to monitor future project direction. It was decided to provide one year no-cost time extension to the contractor, who indicated that he can complete this project with this extension.

Utilization of Waste Renewable Fuels in Boiler with Minimization of Pollutant Emissions

Contract #: 500-98-037

Contractor: Energy and Environmental Research Corporation

Subcontractors: Environmental Research Corporation : University of California, Davis : T.R. Miles Consultants : Stanford University

Contract Amount: \$981,952

Match Amount: \$610,238

Contractor Project Manager: Vladimir Zamansky (949) 859-8851

Commission Contract Manager: Rajesh Kapoor (916) 654-4611

Status: Active

Project Description:

California has a tremendous amount of biomass resources. The state generates over 70 million bone dry tons of biomass residues every year. However, less than six million tons per year are used to help meet the state's electricity needs. Among the barriers to increased use of biomass residues for energy purposes are the relatively high cost of biomass generated electricity, and its perception as having higher air emissions than other renewable or natural gas alternatives. The purpose of this project is to develop an innovative gasification technology that can be retrofitted to existing biomass combustion facilities to help lower emissions while also enabling use of lower cost biomass fuels. The technology, entitled "Close-Coupled Gasification (CCG)", represents a synergistic combination of direct combustion, biomass/waste gasification, and GE-EER's emission control approaches.

The goal of this project is to develop a preliminary conceptual design for a full-scale demonstration facility of CCG technology. The design would retrofit (couple) CCG technology in a California biomass power plant to reduce the NO_x emissions by using the gasified, low-grade biomass/waste fuel. This project is Phase I of a four-phase CCG technology commercialization plan. If analyses prove that the project would be technically and economically feasible, the project developers may decide to design, retrofit and operate the demonstration facility (Phases II and III) and to commercialize the technology throughout California and elsewhere (Phase IV).

This project supports the PIER Program objectives of:

- Improving the environmental and public health risks/costs of California's electricity by developing a lower-cost method for existing, biomass power plants to control NO_x and other pollutant emissions.
- Maximizing the market connection for the project's research results. Specifically, three California biomass power plants, which are potential partners in the full-scale CCG technology demonstration, will participate in this project's design and economic studies to determine if the technology will provide economic and operational benefits to their units.

Proposed Outcomes:

Specific technical outcomes:

1. Design and development of an economic process (demonstration facility), which is capable of converting biomass/waste into gaseous fuel to be used as supplementary cofiring/reburning fuel and NO_x control in California biomass boilers.
2. Produce 10-30 percent of gaseous fuel (by heat input) for a 25 MW biomass boiler.
3. Reduce NO_x emissions up to 65 percent in basic reburning and 90 percent in advanced reburning (AR) and complying with all other California emissions standards.

Specific Economic Outcome:

1. Reduce NO_x control costs by at least 20 percent, compared to the costs of existing NO_x control methods used by biomass boilers owned by Wheelabrator Shasta/Hudson Energy Company, Woodland Biomass, and Wadham Energy.

Project Status:

1. The first project review meeting for phase I of the program was held in the GE-EER office on August 2, 2001. The second critical project review meeting was held at UC, Davis on 18th April, 2002. Rajesh Kapoor, Val Tiangco, George Simons, Elaine-Sison Lebrilla and Prab Sethi from CEC attended the review meeting at UC, Davis.
2. UC, Davis submitted the draft report for the Laboratory Scale Gasification Screening Experiments.
3. Stanford University group performed the laminar flow reactor (LFR) tests on the biomass fuels (rice straw, waste paper, almond shells, wood P, wood W) with different sizes and measured the mass loss for these particles.
4. GE-EER conducted the cofiring and reburning tests with the palletized biomass fuels.
5. GE-EER conducted the process/kinetic modeling to predict the reburning performance of gasified biomass products. This modeling explains the behavior of the data, and suggests the methods to optimize the reburning performance by conducting the parametric evaluations.
6. GE-EER conducted the economic and market analysis to determine the potential applications for CCG technology after a full scale demonstration.
7. GE-EER prepared the production readiness plan to identify the hazardous or non-recyclable materials, critical production processes, equipment, facilities, manpower, and support systems that will be needed to produce a commercially viable product.
8. The contractor submitted the draft reports for all the tasks. The final report is due next month.
9. For the technology transfer, a paper entitled "Integration of Direct Combustion with Gasification for Reduction of NO_x Emissions" was presented and published in the proceedings of the 29th International Symposium on Combustion held in Sapporo, Japan from July 21-26, 2002. A paper entitled "Gasification Combustion Technology for Utilization of Waste Renewable fuels" related to this project was also presented and published in the proceedings of the "Bioenergy 2002 Conference held in Boise, Idaho on September 22-26, 2002. Valentino Tiangco from CEC attended this conference.
10. The contractor has submitted the draft final report in the month of January 2004 and the final meeting will held in the month of February 2004. The project is within the budget and is expected to achieve the goals.

Valley Fig Growers Anaerobic Digester

Contract #: PIR-02-005

Contractor: Valley Fig Growers

Subcontractors: Provost & Pritchard Engineering Group : Williams Engineering Associates :
Capstone Turbine Corporation : Capstone Turbine Corporation

Contract Amount: \$476,002

Match Amount: \$731,223

Contractor Project Manager: Mike Emigh (559) 237-3893

Commission Contract Manager: Zhiqin Zhang (916) 654-4063

Status: Active

Project Progress

Overall, the project has been progressing well in meeting the Commission's expectation and scope of work. The project team members have been very responsible in providing high quality products to meet the Commission's requirement. Without any unexpected delay from permit issues, the project construction is expected to begin in April 2004 and be completed in June 2004.

Project Schedule

Although some tasks are currently three month behind as compared to the original schedule planned due to unexpected permits issues and the time spent on performing different anaerobic digestion systems comparison. The overall project is expected to be completed within the original schedule planned.

Project Budget

The total PIER fund for VFG project is \$476,002. The total match fund for VFG project is \$731,224. To date, the expended PIER and match funds are \$43,877 and \$93,332, respectively. The project is expected to be completed within the original budget planned.

Wind Turbine Company EMD Turbines

Contract #: 500-00-019

Contractor: Wind Turbine Co.

Contract Amount: \$1,300,000

Contractor Project Manager: Doug Jung (707) 523-4585

Commission Contract Manager: Michael Kane (916) 654-7119

Status: Active

Project Description:

The purpose of this project is to transition to Phase II in the development and demonstration of a cost effective, next generation wind turbine capable of producing electricity at prices that can compete with conventional electricity generation systems (fossil fuel, natural gas). The objectives are to develop and to test a lower cost, grid-connected, 500kW commercially viable wind turbine (EMD) scalable to 750kW at a California site. The site has been identified as the Fairmont wind site located in Southern California. During Phase I of the project funded under a previous contract (500-97-032), a prototype version of the innovative turbine was successfully designed, developed and demonstrated at the National Renewable Energy Laboratory (NREL) test facility in Colorado.

The 250kW prototype (POC) is a horizontal-axis, 2-bladed, downwind turbine and has amassed over 1000 hrs in operation in attended and unattended production mode combined. The POC remains a valuable development and test platform for new modifications and turbine studies. Leveraging off the successes and lessons learned from the POC, realizing the cost saving benefits of the innovative lightweight design, and flap-motion control mechanism will be further enhanced and demonstrated using the EMD in typical California Class 5 to Class 6 wind conditions (approximately 13-20 mph). The goal is to develop and test the 2-bladed, horizontal-axis system at 500kW and scale up to 750kW. The machine will be suited for both grid-connected and for standalone applications in combination with other generation and energy storage options.

This project supports the PIER Program objectives of:

- Improving the energy cost/value of California's electricity by developing a lower cost wind turbine capable of producing electricity at prices that can compete with conventional electricity generation.
- Improving the environment, public health and safety of California's electrical system by promoting "zero" emissions electricity generation using alternative energy solutions and by reducing air pollution and global warming.
- Improving electricity reliability/quality/sufficiency by using a generation capability to reduce dependence on fossil fuel resources and improving "free" fuel resources as protection from fuel price volatility.
- Strengthening the California economy by bringing advance wind turbine technology that will require a multi-disciplinary pool of engineers, support personnel to the industry.
- Providing greater choices for California consumers by providing green energy alternatives.

Proposed outcomes:

1. Bring to market readiness a commercially viable and competitive turbine.
2. Provide electrical power to the California grid.
3. Produce a "free" and "clean" fuel generation system to provide reliable and cost competitive energy alternatives to consumers.

4. Advance turbine design and manufacturing with an innovative lightweight, flexible design to reduce structural loads and improve turbine reliability and service life.
5. Put California back into the spotlight as a leader in wind energy resources.
6. Bring wind turbine technology and know how back to California and to the U.S. by advancing the technology, improving the workforce and creating new job opportunities.

Project Status:

The 500kW EMD has been installed at a site near Lancaster, California. The turbine experienced a tower-blade strike after approximately 70 hours of operation, damaging one of the blades. Both blades were removed and shipped to NREL for testing to determine cause of the incident. Based on the NREL findings, control and protection software has been upgraded to prevent additional strikes. The EMD-1 was refitted with a pair of off-the-shelf blades and resumed operation in March 2003. In May 2003, EMD-1 suffered a failure of the main rotor shaft, rendering the turbine inoperable. For safety reasons the turbine was dismantled. The Commission issued a partial stop work order to allow the contractor to determine the reason for the failure. In conjunction with NREL, an independent failure analysis was conducted and initial findings indicated the failure to be related to the previous blade strike event. The analysis also did not find any inherent flaws in the two-bladed downwind technology, but suggested further load analysis to be performed for the design. The Commission authorized WTC to complete loads analysis for the EMD-2 design based on recommendations. An independent technical due diligence of the technology and WTC's organization and operation structure was also performed. Draft final reports and due diligence results have been provided, and project close-out is expected by March of 2004. Though the future of WTC is uncertain at this time, it is believed that the two-bladed, downwind technology and load reduction concepts have potential for future applications. NREL and the CEC are continuing to pursue load reduction concepts similar to those proposed by WTC to help develop a lower cost wind technology capable of operating in low wind speed regimes.

REN Projects Completed in 2003

Collins Pine Co. BCI Cogeneration Project

Contract #: 500-98-043

Contractor: Collins Pine Company

Subcontractors: BC International Corporation : National Renewable Energy Laboratory (NREL) : Plumas Corporation : Kemestrie : TSS Consultants : ProForma Systems, Inc. : Tembec, Inc. : Raphael Katzen Associates International, Inc. : CIFAR

Contract Amount: \$1,148,961

Match Amount: \$382,274

Contractor Project Manager: Wade Mosby (503) 417-7755

Commission Contract Manager: Zhiqin Zhang (916) 654-4063

Status: Cancelled

Project Description:

The purpose of this project is to determine the technical and economic feasibility of integrating a new biomass-to-ethanol facility with an existing biomass power plant, located in Chester, California. If feasible, these two facilities would be operated together and become customers for each other's products. The ethanol facility would produce lignin for sale to the biomass boiler, which it would use to generate electricity and steam. In addition, the biomass power plant would generate electricity and steam for sale to the ethanol facility.

This project seeks to lower the biomass power plant's electricity-generating costs so that it can become more cost-competitive after subsidies for renewable energy power plants expire in 2004. The lignin fuel supply from the ethanol facility may help to lower the biomass power plant's costs of generating electricity. The ethanol facility would also generate income by producing and selling ethanol and other value added co-products to customers outside of Chester, CA. The project is Phase I of a four-phase effort. If the results of Phase 1 are technically and economically positive, then facility developers may proceed with subsequent phases to design, permit, finance, construct and operate the ethanol facility.

This project supports the PIER Program objectives of:

- Improving energy cost/value.
- Improving the environment, public health and safety.
- Improving electricity reliability, quality and sufficiency.
- Address important RD&D gaps.
- Providing greater choices for CA consumers.
- Connecting to near-term market applications.

Proposed Outcomes:

1. Improve system reliability and power quality of California's electricity by seeking a cost-effective way to operate a distributed generation power plant in a rural area, which is prone to electricity supply disruptions.
2. Maximize market/economy connection by providing positive impacts to California local economies by the creation of new jobs and new tax revenues in a rural area.
3. Determine whether the ethanol facility can produce up to 20 million gallons per year of ethanol from softwood feedstock using BC International (BCI) technologies.
4. Determine whether lignin from the ethanol facility can partially displace the existing fuel of Collins Pine biomass power plant by 30 percent to 60 percent.

5. Identify at least one co-product, other than lignin or ethanol, which can be produced by the ethanol facility.
6. Reduce the cost of electricity production at the Collins Pine biomass power plant by at least 1.5 cents/kWh.
7. Identify at least one co-product, other than lignin or ethanol, which can be produced by the ethanol facility and has a value of at least \$2/pound.

Actual Outcomes:

In October of 1998, the Commission signed the Contract with Collins Pine Company to fund a research, development, and demonstration project under the Public Interest Energy Research (PIER) program. The total PIER budget to this contract is \$1,148,961. The match funding of \$375,274 is provided by DOE/NREL. The project was originally scheduled to be completed by December 2000. The project completion schedule was extended to December 31, 2001.

The Energy Commission (Commission) issued a stop work order to this contract on September 19, 2001 due to lack of deliverables due from subcontractors, in particular BC International (BCI). The Commission sent a stop work order following up letter that included a list of lacked deliverables on October 11, 2001. To respond BCI's comments provided to the stop work order following up letter, the Commission sent a response letter on December 4, 2001 to address remaining specific issues regarding subtasks/deliverables. The issue of the pilot scale results and the ability to continue testing at Collins Pine with the generated "simulated" lignin was discussed at length with DOE/NREL and the project team at a December 20, 2001 CPR meeting at the Energy Commission.

Based on a review of the documentation submitted, we believe that BCI has still not adequately responded to the issues on the project. The two remaining outstanding issues with this project include:

1. Lack of fundamental data associated with ethanol process validation activity. Examples of the missing fundamental information include material and energy balance data for all process and utility streams, process flow diagrams, sized equipment specification, and cost information.
2. Ability of the electricity generation side of the facility to use the "simulated" lignin from the ethanol generation side as a fuel.

The remaining issues pose a serious question on the continuation of this contract. The Commission Contract Manager agreed and recommended to the Commission's Research and Development Policy Committee that the contract be terminated. The recommendation to terminate the contract was heard and approved by the Policy Committee on March 20, 2003.

Project Status:

The contract was terminated on April 14, 2003.

Improving Energy Recovery at the Geysers Geothermal Field by Delineation of In-Situ Saturation

Contract #: PIR-00J-004

Contractor: Stanford University

Contract Amount: \$258,781

Match Amount: \$66,780

Contractor Project Manager: Roland Horne (650) 723-9595

Commission Contract Manager: Gail Wiggett (916) 653-7551

Status: Completed

Project Description:

The purpose of this project is to develop an understanding of present and past fluid saturation patterns at The Geysers geothermal field, using:

1. Laboratory measurements on actual rock core samples from the reservoir.
2. Inferring saturations from field production data, by applying mathematical modeling methods developed at Stanford University.

The Geysers geothermal field is the largest in the world, representing an important fraction of California's electrical power generation capacity. Over the past ten years, energy production from the field has been falling as the reservoir "matures." Recent activities of wastewater injection into The Geysers have indicated that it may be possible to slow if not reverse the decline in energy production. However, the ultimate energy output for electricity generation and the optimal strategy for increased injection of wastewater are uncertain because of the difficulty in determining the distribution and flow characteristic of the underground fluids. Recovering energy from a geothermal reservoir requires that mass be withdrawn from it. The basic components of the resource at The Geysers are its reserves of steam and immobile, or in-situ water. Under exploitation the vapor-dominated field can be depleted of water in some places, to form a dry or superheated zone. There is then a recharge of steam from boiling of the immobile water. Even though the steam is the principal recovery fluid, by mass the immobile water is a much larger component of the reservoir fluid than the steam. Therefore it is important to quantify the immobile water in the reservoir. Knowing the immobile water saturation will provide better understanding of the fluid storage capacities of the rocks. This is valuable for estimating the performance of a geothermal reservoir and its capacity for further exploitation.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by helping to provide reliable base load electric power.
- Improving the environment, public health and safety by providing data that can be used to help maintain electric production from the nation's largest non-hydro renewable energy source.
- Improving electricity reliability/quality/sufficiency of California's electrical system by providing information that will be help to maintain the viability of a major source of renewable energy.
- Strengthening the California economy by using an indigenous energy source within the state.
- Providing greater choices for California consumers by helping to prolong the life of The Geysers and increasing the availability of "green" power.

Proposed Outcomes:

Production at the Geysers has been in decline in recent years, until large-scale water reinjection, notably from the Lake County Sanitation District pipeline, began to renew the resource. An additional large-scale reinjection pipeline (the Santa Rosa pipeline) came on-line in late 2003. Knowing where saturation occurs now and where it occurred in the past is expected to improve managers' ability to make strategic decisions about operations, development and management, by aiding in understanding where exploitation has led to dry-out and where immobile water mass might be, or might have been, rejuvenated by injection. This can help in designing locations and timing of large and small scale injection projects. Presenting results of the project in meetings and journals will benefit the technical research community and provide a conduit for practical application.

Actual Outcomes:

Historical records of well pressure, temperature flow rate and enthalpy from wells distributed over The Geysers area, operating in different time periods and in different operating units, were gathered from public and private sources to provide as complete a snapshot as possible of conditions over time and space in the resource field. Data analysis used a model developed by the Stanford team to infer the historical in-situ water saturation at The Geysers. The researchers were able to show that well performance data history can be used to infer in-situ water saturation. Using the data from the wells and the model, the team determined the stable initial and dry-out subsurface temperatures for individual wells in the field, and computed the in-situ water saturation in the vicinity of those wells. By using wells that started operation over a range of time, the team inferred the evolution of saturated conditions in the reservoir. They also were able to determine the variation in saturation from one area to another within the reservoir and to identify superheated areas. This work involved analyzing the data for over 500 wells for which records are available. This work identified 177 wells that had become superheated and 147 wells that are inferred not to have reached superheat. The remaining 179 wells in the database have data that is too sparse to observe temperature-pressure trends. Most of the superheated wells are in the northwest portions of the field. The saturated (i.e., not superheated) wells are mostly in the southeast positions of the field.

The team also investigated the possible effect of increase in the calculated saturation values due to artificial reinjection. Reinjection influence was simulated using TOUGH2. Simulations varied the flow rate and location of reinjection with respect to nearby production wells. It was found that higher injection flow rates and proximity to producing wells increases the apparent saturation values. This influence may explain the apparently higher in-situ water saturation in the Southwest zone of The Geysers field. It is likely therefore that optimizing injection rate, location, and possibly temperature can be used to increase local apparent saturations in the vicinity of a producing well.

To facilitate technology transfer, make the results of the work available to the operating companies, and make the methods known to the research community, several papers were prepared and presented in meetings and journals. Practical application of the results of this work will need to be made by the field operators. Electronic and hard copies of these were part of project submittals and are included in the Commission's files. The Final Report for the project will be available through the Energy Commission's website and in the Commission library.

Project Status:

The project has been completed.

Renewable Technology Strategic Information

Contract #: 500-02-028 **Project #:** 15

Contractor: Electric Power Research Institute (EPRI)

Project Amount: \$45,000

Contractor Project Manager: Chuck McGowin (650) 855-2445

Commission Contract Manager: George Simons (916) 654-4659

Status: Completed

Project Description:

Renewable energy technology development and deployment are proceeding rapidly throughout the world as power agencies and project developers respond to the growing demand for new green power sources and technology developers continue to improve the efficiency and cost performance of renewable technologies. As a result, renewable technology status, performance, cost, installed capacity, markets, and other characteristics continue to change rapidly. This project maintains an up-to-date and objective strategic assessment of renewable technology for use in strategic planning and decision making.

This project supports the PIER Program objective of:

- Providing greater choices for California consumers by supporting compilation and updates of renewable technology development and deployment information.

Proposed Outcome:

1. A status report and regularly issued updates that describe renewable technology status including: performance, cost, installed capacity, and markets.

Actual Outcome:

1. Technical Report, Renewable Energy Technical Assessment Guide (TAG-RE), EPRI Product # 1004938.

Project Status:

The project has been completed.

REN Projects Completed in 2002

Application of Small Modular Biopower System for Power Generation from Forest Residue

Contract #: 500-99-029

Contractor: Community Power Corporation

Subcontractors: Shell International Renewables : National Renewable Energy Laboratory (NREL)

Contract Amount: \$645,827

Match Amount: \$609,695

Contractor Project Manager: Robb Walt (303) 933-3135

Commission Contract Manager: Prab Sethi (916) 654-4509

Status: Completed

Project Description:

The purpose of this project is to design, develop and demonstrate a stand-alone, small modular biopower (SMB) system rated at 12.5 kW for a distributed generation application providing both electricity and heat using two different types of forest residue.

This project is Phase II of an SMB initiative co-funded by the National Renewable Energy Laboratory (NREL)/US Department of Energy (US DOE). In this Phase, the Contractor shall design, fabricate and test two SMB systems namely NREL SMB and PIER SMB. The NREL SMB project is funded by NREL/US DOE and Shell International Renewables, Ltd. for a rural electrification project in the Philippines. The PIER SMB is funded by PIER and co-funded by NREL/US DOE. The Contractor shall design, fabricate and test PIER SMB, based on lessons learned in NREL SMB, for combined power and heat application at Tsemeta Forest Regeneration Complex, Hoopa, California. Phase I of the SMB initiative is a feasibility stage, completed and funded mainly by NREL/US DOE and not PIER funds.

This project supports the PIER Program objectives of:

- Improving environmental and public health costs/risk of California's electricity by mitigating air quality impacts and reducing environmental risks. If successful, this technology will provide beneficial means of forest residue disposal, reduce wildfires, and reduce air pollution from in-forest burning of slash.
- Improving the reliability/quality of California's electricity by removing barriers to distributed generation technology.

Proposed Outcomes:

1. Proposed Technical Outcomes:

The overall technical objective of this project is to develop and demonstrate a 12.5 kW small modular biopower system in a displaced retail, combined heat and power application, and collect the data needed to develop the scale-up path to a family of commercially viable systems in California.

The specific technical objectives are:

- Provide up to 12.5 kilowatt electric (kWe) and 20 kilowatt thermal (kWt) power to the proposed on-site load.
- Provide 220 volts, 3 phase power for the proposed load in parallel with the grid
- Operate with no more than one operator.
- Provide 12.5 kWe power using two of the following feedstocks: Oak, Alder, Madrone and/or Douglass Fir.

Renewable Energy Technologies

- Incorporate system improvements based upon data collected during operation.
 - Translate operating performance of a 12 kW system into clear technical requirements for development of a family of small modular biopower systems between 12 kW and 500 kW.
 - Achieve combined heat and power efficiencies of greater than 60 percent. Electrical efficiency to be no less than 18,000 Btu/kWh (higher heating value (HHV)).
 - At peak power of 12.5 kW_e, the small modular biomass (SMB) system will meet or exceed California's emission standards for a 4 cylinder automobile internal combustion engine. Nitrogen oxides (NO_x) emissions of engine no greater than 1,500 ppm (at full load, 3% O₂). Particulate matter (PM) emissions no greater than 5 ppm.
2. Proposed Economic Outcomes: The overall economic objective of this project is to achieve competitive financial performance for a family of distributed generation applications of the SMB system, both on-grid and off-grid.

The specific, cost objectives for the minimum and maximum size ranges are shown below. This assumes the global sales of SMB system of 1000 units a year.

- 500 kW (grid-connected).
 - Capital cost of \$600 per kW.
 - Electricity cost of less than 7 cents per kWh.
 - Heat cost less than \$0.70 per therm.
- 12 kW (grid-connected and off-grid).
 - Capital cost of \$1,000 per kW.
 - Electricity cost of less than 15 cents per kWh.
 - Heat cost less than \$1.20 per therm.

Actual Outcomes:

1. The project kick-off meeting was held at Hoopa Valley on November 1, 2000. In addition,
 - Task 2.1 Develop, Install and Operate NREL-SMB:
 - The work related to shakedown testing of the first small modular biopower system developed under Phase 2 contract with NREL was completed. Endurance runs at CPC generated 1 MWh of electricity and 145 hours of operation. The unit was shipped to the Philippines in February 2001, and was installed and commissioned on April 2, 2001 in Alaminos, Philippines for the field endurance testing.
 - Task 2.4 Build/test PIER-SMB (Test Bed):
Preliminary layout of the SMB system at the Hoopa Forest Regeneration Complex was completed. The system was installed. Testing and analysis was performed.
 - Task 2.9 Deploy PIER-SMB/CHP:
Modifications were completed to test the system for combined heat and power. A heat exchanger was fabricated and installed on the PIER-SMB to collect waste heat and deliver hot water to the greenhouse.
2. The PIER-SMB was performance tested. In addition, the system was grid connected and was tested in the combined heat and power (CHP) mode. Following are the project outcomes:
 - System was operated in CHP mode at 12.5 kW_e and 20 kW_{th} delivered to the hot water system at Hoopa.

Renewable Energy Technologies

- More than 80 operational problems were identified and improvements implemented to the gasifier, cooling and cleanup system, dryer subsystem, and char subsystem during the course of the project.
- The SMB demonstrated a combined heat and power efficiency of 60%.
- NO_x emissions from the engine were typically less than 150 ppm, and hydrocarbon emissions were negligible.

Project Status:

Project was completed early on June 15, 2002.

Design & Optimization of a Solar Fired 2E Absorption Chiller

Contract #: 500-97-035

Contractor: Bergquam Energy Systems

Subcontractors: Richard Christensen, Ohio State University : Sun Utility Network : Thermal Energy Systems Specialists : Instructional Systems.

Contract Amount: \$150,000

Match Amount: \$150,000

Contractor Project Manager: Jim Bergquam (916) 383-9425

Commission Contract Manager: Prab Sethi (916) 654-4509

Status: Completed

Project Description:

This purpose of this project was to optimize the performance of a solar-fired, double-effect absorption chiller that can be used for space cooling of small to medium-sized commercial buildings. In addition, the project will modify and test the solar-fired chiller to determine generator configuration and operating conditions that maximize chiller and system performance.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by reducing electrical consumption during peak demand created by cooling commercial buildings.
- Improving the energy cost/value of California's electricity by replacing packaged, compressor-based air conditioning systems with a lower-cost solar absorption system.
- Improving the environment and public health of California's electricity by replacing CFCs in compression air conditioners with environmentally safe lithium bromide and water as the working fluid in a solar-driven absorption chiller.

Proposed Outcome:

1. A high-efficiency, double-effect absorption chiller that is optimized for coefficient of performance (COP), cooling capacity and operating temperature.
 - Solar collectors will drive the chiller.
 - The chiller will have a coefficient-of-performance (COP) in the range of 1.2 to 1.4, when the first stage generator is operated at high temperature (approximately 300 degrees F).
 - The chiller will have a COP in the range of 1.1 to 1.2, when the first stage generator is operated at low temperature (below 250 degrees F).

Actual Outcomes:

1. Thermodynamic computer models of first stage generator were designed and updated to predict and evaluate performance of the solar-fired double effect absorption chiller.
2. The testing to determine the heat transfer co-efficient of generator tubes was completed.
3. A device was built called the Twister which twists the stainless steel strips for greater heat transfer in the generator. With the inserts, the heat transfer coefficient is increased by a factor of 2 to 3.
4. The chiller was tested with the first stage generator at low temperature as well as high temperature and was demonstrated at the specified performance levels.

Project Status:

The project has been completed.

Development of an Extended Logging Tool for Geothermal Exploration and Field Development

Contract #: 500-97-034

Contractor: Electromagnetic Instruments

Subcontractors: Lawrence Livermore National Laboratory

Contract Amount: \$1,380,709

Match Amount: \$1,407,953

Contractor Project Manager: Michael Wilt (510) 232-7997

Commission Contract Manager: Gail Wiggett (916) 653-7551

Status: Completed

Project Description:

The purpose of this project was to design, manufacture and field test an extended induction logging device for geothermal applications in California. During the 3 year project, hardware and software for a high-temperature and pressure-tolerant logging tool were to be developed and tested in several field trials in California, and if possible, internationally.

This device provides a three dimensional image of the formation resistivity in the vicinity of a geothermal borehole. It can identify electrically conductive regions associated with high temperature fluids and map through-going fractures, which play a crucial role in fluid production in both geothermal and petroleum reservoirs.

The decline of power generation at the Geysers from a peak capacity of nearly 2000 MW to current production of less than 1000 MW emphasizes the need for improved reservoir management. In addition, the cost of geothermal development in new or existing fields is extremely high. The contributions that a subsurface imaging tool like GeoBILT can make to the geothermal industry are important, because improved understanding of a reservoir's fracture systems can help improve the targeting of new geothermal well sites and aid in mapping fractures and permeable zones for production or injection. Other geophysical tools are available, but the Geo-BILT tool is unique in its combined ability to produce 3-dimensional imaging and models at a distance from a borehole AND to operate under rigorous geothermal conditions. Existing commercially available instruments cannot do this.

This project supports the PIER Program objectives of:

- Improving the reliability and quality of California's electricity by providing a tool that can provide improved acquisition of key subsurface data, facilitating better understanding of reservoir fracture systems and formation resistivities, and leading potentially to more effective reservoir management by optimizing field production and coordinating recharge activities.
- Improving the energy cost and value of California's electricity by developing and making available new logging services and enhancing the efficiency of geothermal energy exploration.
- Improving the environmental and public health costs and risks of California's electricity by aiding in developing an environmentally benign renewable energy source.

Proposed Outcomes:

1. Design and construction of instrumentation and accompanying interpretive software that will provide technological solutions to several important problems in geothermal exploration and field development.

2. Provide an instrument that will improve reservoir definition and fracture mapping in geothermal boreholes. This will better define drilling targets and reduce the number of boreholes required to produce adequate steam for power generation.

Actual Outcomes:

1. Successful field tests were conducted at several non-geothermal sites that have known geologic conditions, in order to test the instrument's ability to detect permeability and saturation differences. Field tests under geothermal conditions were conducted as planned at Dixie Valley, Nevada.
2. The first Dixie Valley field test successfully demonstrated that the instrument can operate in high temperatures. This demonstration was a major goal of the project. Significant amounts of valuable data were collected during this test. A second test in Dixie Valley successfully illustrated the instrument's ability to collect 3-dimensional data around the borehole and to image non-horizontal geological structures.
3. GeoBILT holds significant promise for commercialization within the petroleum industry, and remains, at present, the only logging tool available that can operate under rigorous geothermal conditions. There is considerable industry interest in GeoBILT and its further development. Additional new applications of the technology are also being explored, including its use in research studies of seismic zones. Further indication of GeoBILT's perceived potential is given by the acquisition of Electromagnetic Instruments, Inc. by Schlumberger, the world's largest purveyor of geophysical services.
4. EMI personnel made a final presentation of the results at the Energy Commission on 6 December 2002, a copy of which is available through the Commission website. The final report also is available electronically.

Project Status:

The project has been completed. As with many research and development projects, a number of difficulties were encountered that led to delays in the project's schedule. As a result, it was not possible to complete the international geothermal field tests that had been projected as possible tasks late in the contract duration.

Hybrid Solar-Fossil Thermophotovoltaics

Contract #: 500-97-048

Contractor: EDTEK

Subcontractors: Brookhaven National Laboratory : Power Management Systems, Inc. : The Charters Group, Inc. : NML Partnership : Pacific Financial Group

Contract Amount: \$867,945

Match Amount: \$1,917,107

Contractor Project Manager: William Horne (253) 395-8084

Commission Contract Manager: Prab Sethi (916) 654-4509

Status: Completed

Project Description:

The purpose of this project is for EDTEK, Inc. to design, fabricate and test a modular, hybrid solar/fossil-fueled thermophotovoltaic (SFTPV) system that can produce electricity and process hot water 24 hours per day with a recovery efficiency of about 83 percent. In this system, highly concentrated sunlight is directed into a cavity where the surrounding walls are heated to incandescence, the state where visible light is emitted from a hot object. A natural gas flame is also directed into the cavity to heat its walls and excite the PV cells, as does the concentrated sunlight.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by developing a new distributed generation technology.
- Improving the environmental and public health costs/risks of California's electricity through partial use of solar energy, a renewable and non-polluting energy source.

Proposed Outcomes:

Develop, manufacture and demonstrate a pre-production hybrid prototype SFTPV cogeneration power system that can produce economically competitive electric power and thermal energy on a 24-hour basis. The SFTPV power system will convert sunlight to electricity with 25 percent overall efficiency and natural gas to electricity at an overall efficiency of 20 percent while producing process grade hot water at a recovery efficiency of 83 percent.

Actual Outcomes:

The contractor has worked with Cornell University, the University of Houston, and NREL to use ion beam lithography process and e-beam lithography to prepare stencils for the pre-filters.

Additionally:

1. The gallium antimony (GaSb) PV cells were assembled into arrays for the test unit and final interconnections were completed.
2. The prisms were fabricated and the reflecting coatings were applied. A dish mounting and tracking system was designed.
3. A test of hydraulic tacking mechanism has been successfully completed.
4. The solar concentrator dishes were fabricated, and the smoothing, reflective and glass protection coatings were applied.
5. The SFTPV system was tested as required per specifications.

Project Status:

The project has been completed.

Natural Gas Cofiring in Biomass Fueled Boilers

Contract #: 500-97-040

Contractor: Gas Research Institute

Subcontractors: ARCADIS Geraghty & Miller International : COEN Company, Inc. : Burney Mountain Power : Fairhaven Power Company

Contract Amount: \$655,702

Match Amount: \$731,784

Contractor Project Manager: Isaac Chan (773) 399-5411

Commission Contract Manager: Prab Sethi (916) 654-4509

Status: Completed

Project Description:

The purpose of this project is to develop and retrofit low NO_x gas cofire technology on two biomass fired industrial power boilers at Burney Mountain Power and Fairhaven Power. With biomass, the high fuel moisture level and high fuel quality variability reduce electric competitiveness and increase environmental compliance costs. By firing small amounts of gas, approximately 10 percent of total heat input, operators can control the combustion process and avoid the usual problems that accompany combustion of wet biomass. Cofire offers an independently controlled combustion zone with higher temperatures, resulting in faster load response, better CO and opacity burnout, reduces carbon in the ash, and faster, cleaner startup. These benefits are essential for biomass to compete in the volatile deregulated power market that requires greater responsiveness than is now possible.

In this project, GTI will subcontract the low NO_x burner development to the cofire burner developer, Coen. The low NO_x burner will retain the high-pressure drop feature used earlier, but employs segmented fuel gas/ combustion air zones and possibly induces an enhanced draw of (combustion) air using the properties of the (fuel) gas stream. The prototype burner will be installed in two northern California biomass power plants: Burney Mountain Power and Fairhaven Power. At Burney, cofire will allow recovery of lost derate and allow peak revenue load dispatch to effectively meet changing power demand. At Fairhaven, cofire will recover lost derate and allow compliance with CO and NO_x regulations.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by developing a method for improving the economics of grid-connected, distributed electricity generating biomass facilities.
- Improving environmental and public health costs/risk of California's electricity by mitigating air quality impacts from biomass combustion by cofiring biomass with natural gas within an independently controlled combustion zone with high-temperature, turbulent mixing. The low NO_x feature is unique to California, and this demonstration should facilitate cofire permitting at other biomass facilities.
- Impacting local and state economies by preserving employment opportunities in rural areas where these biomass facilities are typically located.

Proposed Technical Outcomes:

1. Develop a low NO_x cofire burner for application to biomass fueled boilers.
2. Apply the low NO_x cofire burner to increase the load following capability and turndown for Burney Mountain Power.

3. Apply the low NO_x cofire burner to reduce CO emissions and recover lost derate with wet wood at Fairhaven Power.

Proposed Economic/Cost Outcomes:

1. Apply cofiring at Burney Mountain Power to capture high revenue power peaks and avoid low revenue periods to allow operation in the deregulated power market and reduce the break-even power price.
2. Apply cofiring at Fairhaven Power to recover lost derate with wet wood and accrue incremental power sales revenue over the differential fuel price.

Actual Outcomes:

1. Burner system installation on the 10 MW-boiler at Burney Mountain Power plant in Burney, California was completed in March 2000. A new gas pipeline from the Pacific Gas & Electric main transmission line to the boiler was installed. Burner start up and system testing and performance optimization was performed during 2001 and 2002.
2. Required modifications to reduce NO_x emissions and performance optimization of Fairhaven Power plant in Eureka, California were incorporated during a scheduled plant outage.

Project Status:

The project has been completed.

PowerGuard California Manufacturing

Contract #: 500-97-049

Contractor: Powerlight Corporation

Subcontractors: Pulse Energy Systems : Trace Technologies, Inc. : Colorado State University : Augustyn + Company : T. Clear Engineering : Feldman, Waldman and Klein : Solarex : Ananda Power Technologies

Contract Amount: \$958,991

Match Amount: \$1,994,421

Contractor Project Manager: Thomas Dinwoodie (510) 540-0550

Commission Contract Manager: Joe McCabe (916) 654-4412

Status: Completed

Project Description:

The purpose of this project is to expand grid-connected markets for PowerGuard® systems by reducing component and system manufacturing costs, enhancing system reliability, and obtaining specific certifications. PowerGuard® is a rooftop photovoltaic (PV) system providing electrical power. Furthermore, this project established a new California manufacturing facility, using the automated and semi-automated fabrication innovations developed under this contract.

This project supports the PIER Program objectives of:

- Improving the reliability of California's electricity system by developing a renewable, distributed-energy technology.
- Improving the environmental and public health costs/risks of California's electricity by deploying a renewable energy source which does not emit NO_x (nitrous oxides), SO_x (sulfur oxides), and CO₂ (carbon dioxide) when generating electricity.
- Positively impacting California's economy by creating new manufacturing jobs.

Proposed Outcomes:

1. Reduce component and system manufacturing costs.
2. Enhance system reliability.
3. Obtain specific certifications.

Actual Outcomes:

Over the course of this contract, many improvements were made to the PowerGuard product and manufacturing process. These enhancements have reduced the cost of PowerGuard installations, improved the quality and reliability of the PowerGuard product, added features to PowerGuard systems, and provided paths to new markets. A summary of the major accomplishments is listed below:

1. Production rate rose from 200 tiles per 8-hour shift to more than 500 tiles per 8-hour shift.
2. System cost of PowerGuard was reduced by 38%.
3. Balance of System cost was reduced by 68%.
4. Quality of PowerGuard was improved through the implementation of improved production tools and inspection equipment.
5. A sloped PowerGuard tile design was developed.
6. A comprehensive warranty was developed for PowerGuard systems.
7. Extensive wind tunnel testing was used to refine the PowerGuard tile design and to develop installation criteria for a wide variety of conditions and geographical locations.

8. Integrated design software was developed using an off-the-shelf platform to simplify the design of PowerGuard systems by Value-Added Resellers.
9. Seventeen PowerGuard tiles, using PV modules from different manufacturers, have been listed by UL.
10. PowerGuard accessories such as curbs, T-harnesses, and standardized combiner boxes have been submitted to UL for listing.
11. PowerLight has applied for certification of PowerGuard by the International Conference of Building Officials (ICBO).
12. All required tests have been completed to allow the use of the CE mark, allowing the sale of PowerGuard into the European Union.
13. All test required by the International Electrotechnical Commission (IEC) and Institute of Electrical and Electronics Engineers (IEEE) standards have been passed.
14. Modular and standardized PowerGuard system packages were developed to reduce the cost of small systems.
15. An installation manual and training program was produced for installing PowerGuard systems.
16. Clean-up and waste management processes have been improved leading to the recycling of almost all waste products.
17. PowerLight has ensured that the production of PowerGuard conforms to National Environmental Policy Act (NEPA), Occupational Safety and Health Administration (OSHA), and all other applicable federal and state regulations.

Project Status:

This project is completed, under budget, on time and is providing royalties to the State of California. Many accomplishments were achieved including:

- Increased production rates.
- Reduced system costs.
- Increased product quality.
- UL listings.

PowerTherm Product Development

Contract #: 500-97-046

Contractor: Powerlight Corporation

Subcontractors: Advanced Thermal Technologies, Inc. : Sealed Air Corp. : Kathabar, Inc. : David Roodvoets

Contract Amount: \$542,362

Match Amount: \$1,052,361

Contractor Project Manager: Thomas Dinwoodie (510) 540-0550

Commission Contract Manager: Joe McCabe (916) 654-4412

Status: Completed

Project Description:

This purpose of this project is to test a commercial photovoltaic/rooftop solar energy collector system providing electric power and thermal energy from sunlight. The integration of a solar-thermal component with the Contractor's PowerGuard® photovoltaic system will create a hybrid photovoltaic/thermal (PV/T) system, called PowerTherm™. This technology is suitable for buildings with flat to moderately sloping roofs and will increase the economic value of PV roof-tile systems for commercial building owners by providing them with two ways to lower their energy utility costs: PV-electrical generation and solar hot-water production for on-site use.

The PowerGuard® product was substantially advanced under a product R&D contract with the Commission's Energy Technologies Advancement Program and has been successfully tested in dozens of applications internationally. PowerGuard® incorporates state-of-the-art PV technology with extruded foam backing into roofing tiles. These tiles, or panels, are electrically connected to an inverter that feeds quality AC Power to the building's electrical system at or near peak load demand periods for electricity suppliers. This technology can be integrated into new and re-roofing projects, or readily applied over existing roofs.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity system by developing a distributed-energy technology.
- Improving environmental and public health cost/risks of California's electric system by deploying a renewable energy source that does not emit nitrous oxides, sulfur oxides, and carbon dioxide when generating electricity.

Proposed Outcomes:

1. Research, develop, and demonstrate a cost-effective PowerTherm™ product for commercial and residential building owners.
2. Improve heat transfer between the PV laminate and solar-thermal absorber by 29 percent
3. Increase the thermal performance of the overall system by 38 percent.
4. Improve the overall system efficiency by 98 percent over side by side PV and thermal collectors.
5. Achieve a net (thermal-only) system production tile cost of less than \$6 per square foot.
6. Achieve a thermal component payback of less than 5 years in specified markets.

Actual Outcomes:

1. Identified lucrative target markets for PowerTherm: through extensive market analysis and a thorough assessment of product capabilities, commercial and residential pool heating applications in Hawaii and California were identified as ideal near-term markets for this product.

2. Created initial product concept: by leveraging the successful product development and manufacture of PowerLight's flagship product, PowerGuard®, PowerLight quickly initiated development and testing of its first PV/T product concept.
3. Developed a unique product: through design iteration, materials research, testing, and development of supplier relationships, PowerLight created a unique, high quality product which uses inexpensive flexible thin film technology bonded to commercially available unglazed solar thermal collectors. Each 4'X10' collector will produce approximately 315 kWh of electricity and 2,100 kWh of heat annually for swimming pools in a California climate.
4. Developed advanced manufacturing and fabrication techniques: improvements in the manufacturing process were made by reducing both cost and cycle time. Design and development of unique lamination equipment and materials led to significant progress toward product commercialization.
5. Deployed six successful demonstration systems: these systems were installed and monitored at two sites in California and one in Hawaii for testing and performance verification purposes.
6. Researched applicable certifications needed for commercialization: these included ICBO, IEC and UL certifications. UL conducted a design review of PowerTherm.
7. Developed business and marketing strategies: PowerLight developed a finance packaging plan, identified and built alliances with key industry partners, and developed installation, operation, and maintenance plans for the product.
8. Developed equipment that can be used both for production and further research.
9. Optimized critical manufacturing process parameters: through iterative testing and trial manufacturing runs, these parameters were adjusted in order to achieve high quality product parts.
10. Produced full-sized prototypes for certification and field-testing purposes: demonstration systems were installed to monitor performance and reliability. In addition, a full sized system has been sent to FSEC for evaluation.

Project Status:

This project is completed, under budget and on time.

Renewable Technology Options & Green Power Marketing - Program 84

Contract #: 500-00-023 **Project #:** 60-61

Contractor: Electric Power Research Institute (EPRI)

Project amount: \$45,522

Match amount: \$503,463

Contractor Project Manager: Chuck McGowin (650) 855-2445

Commission Contract Manager: George Simons (916) 654-4659

Status: Completed

Project Description:

The purpose of these EPRI projects is to provide information on the status, performance, and cost of renewable generating technologies, as well as information to support green power marketing. The program supports projects that address field verification and lessons learned in wind, solar photovoltaics, solar thermal, biomass, geothermal, low impact and emerging hydro, and other renewable energy technologies.

This project supports the PIER Program objectives of:

- Improving the environmental and public health costs/risks of California's electricity by increasing the potential for application of renewables by providing accurate information on performance, energy and non-energy benefits, costs, and best practices.
- Improving the reliability/quality of California's electricity by facilitating the integration of electricity from distributed generation technologies into the State's electricity transmission and distribution system.

Proposed Outcomes:

1. Produce a technical assessment guide to renewable energy that provides accurate information on technology status, installation history, performance and cost for a range of renewable energy technologies, including photovoltaic, solar thermal, wind, biomass, waste fuels, geothermal, and small hydroelectric systems.
2. Develop and deliver information about renewable energy to support public outreach programs, press briefings, presentations and speeches.
3. Conduct field verification evaluations of the performance, cost, reliability, power quality, environmental emissions, and economics of distributed renewable energy generation.

Actual Outcomes:

1. Technical Assessment Guide on Renewable Technologies.
 - The *EPRI Renewable Energy Technology Assessment Guide 2002* (TAG-RE) (1004196) was updated and issued in print, electronic (CD-ROM), and web-based formats. The TAG-RE provides comprehensive, detailed information on the technology status, development issues, performance, cost, installed capacity, and markets for renewable technologies. The 2002 TAG-RE incorporates a shift in emphasis in the PV section from central-station to distributed applications, as a result of projected growth in distributed applications. Because distributed installations require a different economic methodology for estimating costs, the TAG-RE includes new cost calculations based on the Clean Power Estimator. This model was designed by Clean Power Research to provide potential PV owners with an accurate and user-friendly tool for calculating the cost of PV, and is licensed by a number of utilities and public agencies. In addition, TAG-RE users will have access to an online calculation tool. The tool is based on EPRI's TAG calculator, and uses TAG-RE data

for wind, central-station PV, and biomass. With the tool, users can run customized cases to obtain cost and performance data.

2. Renewable Energy Information.
 - This program publishes *EPRI Green Power News* (E207557), a bimonthly web-based newsletter that highlights renewable energy technology and market developments.
 - A renewable energy brochure (1004198) was produced that addresses the status and benefits of solar PV, wind, biomass and low-impact hydro resources and technologies, plus green marketing issues for all renewables.
 - A EPRIweb-based information service, Renewable Energy Current Information Pages, provides continuous updates on renewable energy technology status, performance, cost, installed capacity, opportunities for project collaboration, and state and federal mandates for renewable energy.
 - A renewable energy slide show (1004199) was prepared that contains presentations on the status and benefits of solar PV, solar thermal, wind, biomass, and geothermal generation.
3. Field Verification of Distributed Renewable Energy Generation.
 - The first of a series of technical reports—*Field Verification of Distributed Renewable Energy Generation* (1004205)—was submitted for publication. The report documents results of field verification testing and evaluation.

Project Status:

Project is complete.

Residential Electric Power Security

Contract #: 500-97-047

Contractor: Kyocera Solar, Inc.

Subcontractors: Southwest Technology Development Institute : New Mexico State University

Contract Amount: \$426,343

Match Amount: \$994,799

Contractor Project Manager: Joel Oatman (480) 443-7732

Commission Contract Manager: Joe McCabe (916) 654-4412

Status: Completed

Project Description:

The purpose of this project was to design, assemble, and test a photovoltaic (PV) power system for residential rooftop applications. The project will focus on three aspects of the system:

1. UPG will design, assemble, and test a novel rooftop PV panel attachment and interconnection process.
2. UPG will produce a fully integrated multifunctional dc-ac/ac-dc power collection, conversion, and control unit.
3. Develop an optional low-cost battery unit designed to plug into the Power Unit to provide a dependable supply of energy for critical household loads.

The proposed PV power system will possess features such as low cost, high efficiency, adaptable to a wide range of roof tops, high power quality, and compliance with all NEC, UL, IEEE, and Utility Interconnection Codes and Standards. The developed system is expected to reduce the installed cost of grid connected PV by approximately 34 percent, and improve their reliability by a factor of five.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by increasing reliability over current systems from 10 percent rate of failure to 2 percent rate of failure (a five fold improvement).
- Improving the energy cost/value of California's electricity by optimizing design of residential roof-mounted PV through a system integration approach, increase system modularity to reduce manufacturing costs, and develop standardized hardware and methods for PV/roof attachment to reduce installation costs.

Proposed Outcomes:

1. Develop an advanced version of the multi-functional rooftop PV power processing system with a number of market driven advanced capabilities which do not exist in any commercially available power processing product.
2. Contractor anticipates reducing materials and installation costs (exclusive of the PV module) by 30 percent.

Actual Outcomes:

1. Design revisions of the PV array.
2. Submission of PV Array for UL review.
3. Installation of a production version of the PV Array.
4. Submission of Power Unit CAM files of revised printed circuit boards to vendors.
5. Design revisions of Power Unit electro-mechanical system.
6. Submission of Power Unit for UL review.
7. Design revisions of Energy Storage Unit.

Renewable Energy Technologies

8. Submission of Energy Storage Unit for UL review.
9. Testing of Energy Storage Unit.
10. UL testing of Energy Storage Unit.
11. First draft of Final Report is completed.

Project Status:

The project is completed and the final report will be published on the Energy Commission website.

The Next Generation Turbine Development Project

Contract #: 500-97-032

Contractor: Wind Turbine Co.

Contract Amount: \$950,000

Match Amount: \$6,935,733

Contractor Project Manager: Lawrence Miles (425) 637-1470

Commission Contract Manager: Michelle Pantoya

Status: Completed

Project Description:

The purpose of this project was to design, develop and demonstrate a utility scale wind turbine that will produce electricity at prices that do not need subsidies or premiums to compete in the emerging electricity marketplace. At 250 kilowatts, this turbine is a horizontal axis, 2-blade, downwind turbine that brings together a number of concepts previously employed in other turbines of this design. In addition, this turbine is the first 2-blade downwind configured wind turbine to be developed in over 15 years, and is believed to be the first turbine to be completely designed employing newly available computer analytic codes that model wind turbine behavior and performance. By designing the turbine as a complete system, WTC is able to substantially improve turbine performance while significantly reducing weight compared with conventional wind turbines. Reducing weight lowers manufacturing costs which, together with improved performance leads directly to lower cost electricity. This machine will be well suited for both grid-connected, wind farm applications and for stand alone applications in combination with other generating and/or energy storage technologies.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by increasing the likelihood that wind energy will not only remain a viable source of renewable electricity, but will actually supply a growing share of the electricity consumed in the state.
- Improving the energy cost/value of California's electricity by developing a wind turbine capable of producing electricity at prices competitive with the lowest cost sources of conventional electricity generation currently recognized to be natural gas-fired combined-cycle combustion turbines.
- Improving the environmental and public health costs/risks of California's electricity by reducing air pollution and eliminating emissions that are believed to cause global warming.
- Improving the safety of California's electricity by employing a unique tubular tower design of sufficient diameter to provide an internal passage from the ground to the tower top (nacelle).

Proposed Outcomes:

1. Bring to market readiness a utility scale wind turbine that is cost competitive with other sources of energy generation.
2. Develop and field test a proof of concept wind turbine intended to demonstrate the feasibility of concepts and systems employed in the wind turbine, and to validate the computer codes used in design the turbine through testing.
3. Develop a prototype turbine that is intended to be a commercially viable machine.
4. Enhance the development of a commercial product that provides renewable, clean, reliable and cost competitive energy.
5. Aim at reduced capital costs due to weight reductions in key turbine components.

Actual Outcomes:

The prototype turbine was designed, built and demonstrated at the National Renewable Energy Laboratory (NREL) test site. The project has achieved all technical objectives of incorporating advance design techniques and innovative engineering solutions in the design of the proof of concept model. Although delays were incurred, the project has remained within budget. The POC has amassed nearly 1000 hrs in attended and unattended operation mode. The POC will continue operations and will serve as a testing and instrumentation platform for the development of the EMD in Phase II of the project at a southern California test site. At this time, the POC will remain at the NREL site for continuous testing and monitoring.

Project Status:

Project is complete.

TrueWind Solutions, LLC

Contract #: 500-01-009

Contractor: TrueWind Solutions, LLC

Contract Amount: \$150,000

Contractor Project Manager: Michael Brower (978) 749-9591

Commission Contract Manager: Michael Kane (916) 654-7119

Status: Completed

Project Description:

The purpose of this contract was to develop more accurate and reliable wind resource maps for California using state-of-the-art numerical modeling techniques and site validation data. This effort not only updates the existing annual wind resource map for California produced in the late 1970s, but it will include several enhancements including the incorporation of new meteorological, geographical and terrain data that have been collected but were unavailable back when the original map was produced. Validation of map results will also be performed in conjunction with the modeling effort. These new maps will help to better define wind corridors as well as identify new potential sites for wind energy integration.

The objective of this effort was to produce high-resolution wind maps of California's complex distribution of wind resources, including nearby offshore areas. Maps showing the mean annual and seasonal wind speed and wind power density on a 400m by 400m grid will be generated in electronic and printed format for multiple elevations above ground level (e.g., 30, 65, and 100 meters). The new map will have a resolution of 400 meters squared in contrast to the existing map that has a resolution of 25 kilometers squared. Because of this, the new maps will show more variability in the wind resources than the old map to better help identify promising areas for wind energy development. The new maps will also use Geographic Information System (GIS) software, overlaying significant features such as power lines, park boundaries, and roads to support future wind energy siting and planning decisions and the evaluation of wind energy development opportunities.

This project supports the PIER Program objectives of:

- Improving energy cost/value of California's electricity by accelerating the initial stages of wind project development with reliable wind maps that substantially reduce risk and siting barriers for new developers.
- Improving electricity reliability/quality/sufficiency of California's electrical system by:
 - Providing the most current and reliable information on wind resource data for the state.
 - Providing data for identifying new potential sites for wind energy integration.
 - Providing high-resolution wind data useful for forecasting and optimizing wind resource management.
- Strengthening the California economy by encouraging development of new wind sites and job opportunities.
- Providing greater choices for California consumers by supporting the expansion of clean energy resources and by providing data to make the resources more manageable.
- Improving the environment, public health and safety by providing the most reliable and updated data for basing decisions and integrating with existing infrastructure (transmission) and planning strategies.

Proposed Outcomes:

1. Updated wind resource maps for California with detailed seasonal and altitude variation data needed for planning and forecasting.
2. Access to state-of-the-art numerical modeling technique and expertise to integrate new information in a timely and efficient manner to provide future updates.
3. Web accessible new maps that are in a format that can also be immediately integrated with existing State cartography system (GIS format).
4. Reliable wind resource data to assist wind project developers.
5. Reliable upper altitude (≥ 50 meters) wind data to assist wind turbine manufacturers in developing safe, efficient and affordable wind turbines.

Actual Outcomes:

The project was successfully completed on time and under budget. Selected wind maps are available for download (JPG format) on the Energy Commission web site. Hard copies or GIS compatible data files can be ordered from the Commission Cartography Office at 916-654 3902.

Project Status:

The project has been completed.

REN Projects Completed in 2001

Renewable Technology Options & Green Power Marketing - Target 84

Contract #: 500-00-023 **Project #:** 25-29

Contractor: Electric Power Research Institute (EPRI)

Project amount: \$223,449

Match amount: \$2,792,100

Contractor Project Manager: Chuck McGowin (650) 855-2445

Commission Contract Manager: George Simons (916) 654-4659

Status: Completed

84.1 Information to Support High-Value Photovoltaic Power Applications

84.2 Wind Power Development Support

84.4 Biomass Energy

84.5 Renewable Energy Applications in Distributed Generation

Project Description:

The purpose of this project is to address the barriers renewable energy technologies face in spite of customer enthusiasm, technology advances, and dropping prices. Still needed are standardized technology and control protocols, more efficient operating strategies, and broader definitions of the true benefits of renewable energy. This EPRI target packages objective information and real-world experience focusing on three main options—wind power, photovoltaics, and biomass. Specifically, EPRI will manage California's wind energy forecasting project, and broker other collaborative projects with utilities, DOE and others. EPRI will deliver results in areas including biomass cofiring with natural gas, wind power, a renewable energy technical assessment guide, and photovoltaics. This EPRI target provides information on renewable technology performance and costs, analyzes the energy and non-energy benefits of deploying renewable technologies, and offers an inside look at the working experiences of companies around the world.

This project supports the PIER Program objectives of:

- Improving the environmental and public health costs/risks of California's electricity by increasing the potential for application of renewables by providing accurate information on performance, energy and non-energy benefits, costs, and best practices.
- Improving the reliability/quality of California's electricity by facilitating the integration of electricity from distributed generation technologies into the State's electricity transmission and distribution system.

Proposed Outcomes:

1. Produce a technical assessment guide to renewable energy that provides accurate information on technology status, installation history, performance and cost for a range of renewable energy technologies, including photovoltaic, solar thermal, wind, biomass, waste fuels, geothermal, and small hydroelectric systems.
2. Provide guidelines and expert assistance for selecting, designing, and installing cost-effective photovoltaic systems. P
3. Provide field wind turbine performance and economic data for advanced early commercial wind turbines that have not been widely deployed. P
4. As part of the DOE-EPRI Wind Turbine Verification Program (TVP), conduct an outreach workshop to provide a forum for TVP host utilities, equipment manufacturers, A

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| | community leaders, and others to discuss the results of the TVP program and lessons learned. | |
| 5. | provide information on biomass cofiring projects in the ongoing DOE biomass cofiring field-testing and demonstration program. | P |
| 6. | collect information and assess the impacts of distributed renewable energy power generation on the operations and reliability of microgrid systems. | C |

Actual Outcomes:

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|----|---|---|
| | <ol style="list-style-type: none"> 1. Technical assessment guide on renewable technologies. <ul style="list-style-type: none"> • The <i>EPRI Renewable Energy Technology Assessment Guide</i> (TAG-RE) (1004034) was updated and published. The TAG-RE provides comprehensive, detailed information on the technology status, development issues, performance, cost, installed capacity, and markets for renewable technologies. This product is issued in both print and electronic (CD-ROM) formats. | |
| 2. | <ol style="list-style-type: none"> electing, Designing, and Installing Cost-Effective PV Systems. <ul style="list-style-type: none"> • Researchers applied EPRI-developed information on PV and green power markets to case studies of grid-connected PV and PV-hybrid systems to illustrate best practices. Results are presented in a technical report, <i>Case Studies of Grid-Connected PV Systems</i> (1004037), published in March 2002. | S |
| 3. | <p>Field Verification of Wind Turbine Performance and Economics – As part of the DOE-EPRI Wind Turbine Verification Program (TVP), EPRI helps transfer the experience acquired in TVP wind turbine projects to turbine vendors, wind power developers, government agencies, utilities, and other interested parties so that the lessons learned can be applied to future projects. To date, EPRI has issued 21 reports on project development and operation for seven DOE-EPRI TVP wind projects located in Alaska, Iowa, Nebraska, Texas, Vermont, and Wisconsin. In 2001, EPRI published the following TVP reports:</p> <ul style="list-style-type: none"> • <i>Iowa/Nebraska Distributed Wind Generation Projects First and Second Year Operating Experience: 1999-2001: U.S. Department of Energy-EPRI Wind Turbine Verification Program</i> (1004039). • <i>Kotzebue Electric Association Wind Power Project Second Year Operating Experience: 2000-2001: U.S. Department of Energy-EPRI Wind Turbine Verification Program</i> (1004040). • <i>Wisconsin Low Wind Speed Turbine Project Third Year Operating Experience: 2000-2001: U.S. Department of Energy-EPRI Wind Turbine Verification Program</i> (1004041). • <i>Big Spring Wind Power Project Second Year Operating Experience 2000-2001: U.S. Department of Energy-EPRI Wind Turbine Verification Program</i> (1004042). | F |
| 4. | <ol style="list-style-type: none"> Annual TVP Outreach Workshop. <ul style="list-style-type: none"> • The workshop was conducted and presentation notes published. | A |
| 5. | <ol style="list-style-type: none"> Biomass Cofiring. <ul style="list-style-type: none"> • A technical report – <i>Annual Report on Biomass Cofiring Program</i> (1004601) – was published. The report documents nine years of EPRI/DOE industry engineering | B |

analysis and field testing regarding wood and other biomass fuels cofired with coal in utility coal-fired boilers.

6. D
- istributed Renewable Energy Impacts on Microgrid Systems.
- Researchers developed information on the impacts of solar, wind, small hydro, biomass power on the operation, reliability, power quality, emissions, and economics of microgrid systems. Results are presented in a technical report – *Distributed Renewable Energy Generation Impacts on Microgrid Operation and Reliability, Draft Report* (1004045) – published in June 2002.

Project Status:

The project has been completed.

REN Projects Completed in 2000

California Renewable Energy Technology Market & Benefit Assessment

Contract #: 100-98-001 **Project #:** 26

Contractor: Electric Power Research Institute (EPRI)

Subcontractors: Global Energy Concepts

Project Amount: \$340,352

Contractor Project Manager: Chuck McGowin (650) 855-2445

Commission Contract Manager: George Simons (916) 654-4659

Status: Completed

Project Description:

The purpose of this project is to develop an understanding of the current and future performance and costs of renewable energy technologies and resources in California. The project encompasses a multi-phase program that will complement the market analysis performed by the Renewable Energy Program and quantify the benefits of renewable energy research and development (R&D) programs. It also addresses technological issues confronting the manufacturers and developers of renewable energy systems in California. Project results will include renewable resource maps of California, descriptions of renewable energy technologies and their status, market assessments, likely development pathways, current and projected cost and performance, potential for quantified environmental benefits, descriptions of evolving markets and service, and data on key customers and players in the industry. Renewable energy technologies to be addressed include biomass and waste fuels, geothermal, small hydro, solar photovoltaic, solar thermal, wind power, and ocean or tidal current power.

This project supports the PIER Program objectives of:

- Improving energy cost/value by helping make renewable electricity more affordable, cleaner, reliable, and secure.
- Improving the reliability/quality of California's electric system by identifying issues with a direct impact on research, development and demonstration cost-competitiveness, reliability, dispatchability, and power quality.
- Strengthening the California economy by analyzing market trends, quantifying benefits, and identifying important manufacturers, developers and projects.
- Improving the environmental and public health costs/risks of California's electricity by increasing the proportion of environmentally clean renewable technology in the California energy mix.

Proposed Outcomes:

1. Identify the current status of renewable technology in California, including the type, location, capacity, duty cycle and operating characteristics of renewable energy generation currently deployed in the state.
2. Identify the total market size of each technology in California and how it is affected by regulatory and policy issues such as air quality, utility deregulation, green markets, recovery of stranded costs, and federal tax credits.
3. Assess the economics of renewable energy generation.
4. Identify potential new players in California's renewable energy marketplace.
5. Characterize the technologies most likely to succeed in both large- and small-scale markets.
6. Quantify renewable energy benefits and summarize market data.

Project Status:

The project has been completed.

California Wind Energy Forecasting System

Contract #: 100-98-001 **Project #:** 23

Contractor: Electric Power Research Institute (EPRI)

Subcontractors: Risoe National Laboratory(Denmark) : TrueWind Solutions, LLC : University of California, Davis : Weather Service International

Project Amount: \$508,344

Contractor Project Manager: Chuck McGowin (650) 855-2445

Commission Contract Manager: George Simons (916) 654-4659

Status: Completed

Project Description:

The purpose of this project is to develop a California Wind Energy Forecasting System to forecast the hourly wind generation in the State's wind areas.

The lack of reliable wind energy forecasts, especially for "next day" conditions, threatens to limit the competitiveness of existing wind plants, as well as constrain future installations. Lacking accurate information, owners and operators of existing plants can incur substantial financial risks when entering competitive bidding for real-time and next-day power supply and ancillary service contracts. Missing these opportunities is devastating for current wind energy suppliers, and a deterrent to prospective investors in new facilities.

The development of an accurate forecasting system could boost private sector investment in wind energy facilities while improving grid operations. Accurate wind forecasting would help wind energy compete with other energy sources in real-time and next-day power markets, and help establish a significant, sustainable role for wind energy in California.

This project supports the PIER Program objectives of:

- Improving the environmental and public health costs/risks of California's electricity by increasing the use of pollution-free wind energy.
- Improve the cost/value of California's electricity by reducing the risks faced by wind plant owners and operators that offer cost-competitive power.
- Improve the reliability of California's electricity by increasing the likelihood that wind energy will remain a viable and growing source of renewable electricity.
- Strengthening the California economy by encouraging deployment of new wind plants.

Proposed Outcome:

Develop and test a wind energy forecasting system that will enable wind generation to effectively compete with other energy sources in real-time and next-day power markets. This is likely to accelerate investment in new capacity, helping establish a significant, sustainable role for wind energy in state and regional generation portfolios.

Actual Outcomes:

In 2001 EPRI executed nondisclosure agreements with host wind project operators, R&D contractors, and meteorological consultants involved in the development and testing of wind forecasting systems at multiple wind plant sites in California. Host agreements were executed with SeaWest, which operates the 66.6 MW Mountain View I and II wind project in the Palm Springs area, and WindWorks/Wind Power Partners 1987 and 1988, which owns 90 MW of Kenetech wind turbines at Altamont Pass. SeaWest and WindWorks/Wind Power Partners' operating unit, PowerWorks, Inc. provided access to daily wind resource and generation data

from their respective wind plants. Consulting and R&D agreements were executed with a meteorology consultant and two wind energy forecasting subcontractors. The project development and test period was delayed about 18 months from the original plan due to delays in obtaining the required historical and daily wind resource and turbine generation and availability data from the wind plant operators. In March 2002, the project scope and cost were reduced to ensure that the project could be completed by December 2002. Two subcontractors generated hourly wind speed and generation forecasts and EPRI evaluated the forecast performance vs. observed data for the Altamont and Mountain View wind projects for the 12-month period, October 2001 through September 2002. The results of the project are documented in two reports, to be published by EPRI and posted on the CEC and EPRI websites during early 2003:

- *California Wind Energy Forecasting System Development and Testing Phase 1: Initial Testing* (1007338).
- *California Wind Energy Forecasting System Development and Testing Phase 2: 12-Month Testing and Evaluation* (1007339).

Project Status:

The project has been completed.

Photovoltaic (PV) Chargeport Demonstration

Contract #: 500-97-011 **Project #:** 3

Contractor: San Diego Gas and Electric Company

Project Amount: \$90,000

Contractor Project Manager: Anne Brandon (619) 654-1113

Commission Contract Manager: Jamie Patterson (916) 657-4819

Status: Completed

Project Description:

The purpose of this project was to demonstrate the integration of electricity-generating photovoltaic (PV) panels into a covered parking port to charge electric vehicles. This application of PV will illustrate how the panels can be integrated into the current electrical system for practical applications.

This project supports the PIER Program objective of:

- Improving the environmental and public health costs/risks of California's electricity by providing a clean source of electricity for zero-emission vehicles.

Proposed Outcome:

1. Establish guidelines for future deployment of PV's for electric vehicle charge stations without the need for extensive engineering.

Actual Outcome:

1. This project demonstrated that photovoltaics can be integrated with electric vehicle chargeports to partially offset the amount of electricity used to charge electric vehicles.

Project Status:

The project has been completed.

Renewable Technology Options and Green Power

Contract #: 100-98-001 **Project #:** 18

Contractor: Electric Power Research Institute (EPRI)

Subcontractors: D. Iem Dba Augenstein : Edward A. Holt : Karen Conover : Dr. J. M. Morabito : Thomas Morton : Ron Nierenberg : Rla Consulting : Patricia Weis Taylor : Wind Economics & Technology, Inc. : Ascension Technology : Cedar Falls Utilities : Central & South West Services, Inc. : City of Brownfield, Texas : Cummins Power Generation, Inc. : Fortum Power and Heat : Foster Wheeler Development Corp : Green Mountain Power Company : Kansas Electric Utilities Research Program : Nebraska Public Power District : Nevada Power : New York State Electric and Gas : Pennsylvania State University : Princeton University : Resolve, Inc. : Risoe National Laboratory(Denmark) : Southern Research Institute : Tennessee Valley Authority : University of Delaware : University of Illinois, Urbana : University of South Florida : University of Texas, Austin : York Research Corporation

Project Amount: \$678,480

Match Amount: \$3,694,856

Contractor Project Manager: Dan Rastler (650) 855-2521

Commission Contract Manager: George Simons (916) 654-4659

Status: Completed

Project Description:

The purpose of this project is to address the barriers renewable energy technologies face in spite of customer enthusiasm, technology advances, and dropping prices. Still needed are standardized technology and control protocols, more efficient operating strategies, and broader definitions of the true benefits of renewable energy. This EPRI target packages objective information and real-world experience focusing on three main options—wind power, photovoltaics, and biomass. Specifically, EPRI will manage California's wind energy forecasting project, and broker other collaborative projects with utilities, DOE and others. EPRI will deliver results in areas including biomass cofiring with natural gas, wind power, a renewable energy technical assessment guide, and PV interconnections. This EPRI target provides information on renewable technology performance and costs, analyzes the energy and non-energy benefits of deploying renewable technologies, and offers an inside look at the working experiences of companies around the world.

This project supports the PIER Program objectives of:

- Improving the energy cost value of California's electricity by increasing the potential for application of renewables by providing accurate information on performance, energy and non-energy benefits, costs, and best practices
- Improving the reliability/quality of California's electricity by facilitating the integration of electricity from distributed generation technologies into the State's electricity transmission and distribution system.

Proposed Outcomes:

1. Provide accurate information on wind power technology, markets, and issues to increase the potential for its application in California.
2. Develop a wind forecasting capability to reduce the financial risk for wind generators to bid to supply real-time and next-day wind energy and ancillary benefits to the California Independent System Operator (ISO), Power Exchange (PX), and Automated Power Exchange (APX).
3. Provide accurate information on photovoltaics technology, markets, and issues to increase the potential for its application in California.

4. Provide accurate information on biomass technology, markets, and issues to increase the potential for its application in California.
5. Conduct a Tailored Collaboration entitled "Biomass Cofiring with Natural Gas in California: Phase I Study" to identify feasible options for integrating biomass use with natural gas power systems.

Actual Outcomes:

1. Wind power information.
 - Performance test results were compiled from the DOE-EPRI Wind Turbine Verification Program, which features seven projects conducted throughout the world, documenting data on operations and availability of five different leading technologies. Findings were published in news bulletins and eight technical reports.
 - A report entitled Wind Power Productivity Improvement and Procurement Guidelines was published.
 - Improvements were suggested to the wind technology of Zond, the only large U.S. manufacturer of wind power technology, which is located in California.
 - The EPRI Renewable Energy Technology Assessment Guide (TAG-RE) was published with a section on wind power. The TAG-RE provides comprehensive, detailed information on the technology status, development issues, performance, cost, installed capacity, and markets for renewable technologies.
 - Information was compiled on wind power as part of EPRI's renewable energy briefing materials, brochures, CD-ROM, and web site.
2. Wind power forecasting.
 - Development of a modeling system to issue twice-daily forecasts of hourly wind generation was initiated in parallel by three different companies. Development and testing are to continue in 2001.
 - A report was published on the European Union wind energy forecasting model development and testing.
3. Photovoltaics (PV).
 - The EPRI Renewable Energy Technology Assessment Guide (TAG-RE) was published with a section on solar PV.
 - Information was compiled on solar PV as part of EPRI's renewable energy briefing materials, brochures, CD-ROM, and web site.
 - Guidelines were provided for identifying, planning, and implementing high-value PV systems, as well for interconnection with the grid.
 - EPRI representatives attended meetings of the Utility Photovoltaic Group to assist in planning and execution of the national PV Rooftop Initiative.
4. Biomass.
 - The EPRI Renewable Energy Technology Assessment Guide (TAG-RE) was published with a section on biomass.
 - Information was compiled on biomass as part of EPRI's renewable energy briefing materials, brochures, CD-ROM, and web site.
 - The Biomass Cofiring Applications Guide was produced.
 - EPRI monitored and reported on R&D and commercial products and programs that offer improvements in knowledge or performance of biomass crop and energy systems.

5. Tailored collaboration on biomass cofiring.
 - A report was published presenting the major cost and performance parameters of systems that enable natural gas to be augmented by 10% biomass fuel. The report provides estimates of the extra cost for the electricity to be generated from biomass.
 - Field test results were published from the Bailly and Seward demonstrations.

Project Status:

The Commission's participation in this target ended as of December 31, 2000.

REN Projects Completed in 1999

Photovoltaics

Contract #: 500-97-012 **Project #:** 11

Contractor: Edison Technology Solutions/Southern California Edison

Subcontractors: Utility PhotoVoltaic Group : United States Department of Energy : Emerging Renewables

Project Amount: \$1,000,000

Contractor Project Manager: Steve Taylor (626) 815-0530

Commission Contract Manager: Jamie Patterson (916) 657-4819

Status: Completed

Project Description:

The purpose of this project was to operate and monitor twelve photovoltaic (PV) systems to evaluate their year-round system performance and efficiency. This evaluation was to document that photovoltaics are applicable on a wide scale to the typical building types located in the dense urban areas of Southern California.

This project supports the PIER Program objectives of:

- Improving the environmental and public health costs/risks of California's electricity by documenting the application of a clean electrical generation technology.
- Improving the reliability/quality of California's electricity because PV offers an attractive, environmentally benign renewable energy alternative for distributed electrical generation.

Proposed Outcomes:

Support Edison Technology Service's (ETS) Solar Neighborhood Program by helping to commercialize photovoltaic technology, educate and increase public awareness, and deploy photovoltaics into high-value, high-visibility applications by evaluating system performance and efficiency as compared to expected results, and evaluating the seasonal effects of year-round PV operations in California.

Actual Outcomes:

Properly designed and situated PV systems were shown to operate within 15 percent of their expected system efficiency specifications.

The seasonal effects of the various PV systems showed that with increasing panel temperatures, efficiencies decreased. Conversely, when the panels were cooler at the same irradiance level, system efficiency increased. Increasing daylight hours in the summer increased overall energy production. The decreased panel efficiency occasioned by increased summer temperatures was more than offset by longer daylight hours. Peak power reduction was offset by increased energy production.

Project Status:

The project has been completed.

Solar Two

Contract #: 500-97-012 **Project #:** 10

Contractor: Edison Technology Solutions/Southern California Edison

Project Amount: \$1,200,000

Contractor Project Manager: Kon McQuiston (626) 815-0520

Commission Contract Manager: Alec F. Jenkins (916) 654-4597

Status: Completed

Project Description:

This project completes the testing and evaluation of the 10 MW Solar Two Central Receiver Project. Solar Two uses concentrated solar energy to produce steam for electric generation. It is a proof-of-concept power plant that demonstrates the practical combination of the solar central receiver concept and the use of molten salt as an efficient, nontoxic heat transfer and energy storage fluid. The central receiver/molten salt design is presently the only practical technology for collecting and storing solar thermal energy for electric generation on demand, whether that demand is hours or days after the energy has been collected.

This project supports the PIER Program objectives of:

- Improving the reliability/quality of California's electricity by using a sustainable energy resource to diversify the State's electricity supply system.
- Improving the energy cost/value of California's electricity by overcoming the intermittent nature of traditional solar electric generation so that even base load power can be provided.
- Improving the environmental and public health costs/risks of California's electricity by using a zero emission generation technology with a nontoxic energy storage medium (molten salt).
- Improving the safety of California's electricity by using a nonflammable energy transfer fluid (molten salt).

Proposed Outcomes:

1. Test and validate the technical characteristics including performance of the nitrate salt receiver, energy storage system, and steam generator subsystems and generation dispatch capability.
2. Improve the accuracy of economic projections for commercial projects by increasing the database for capital, operating, and maintenance costs.
3. Document overall project results for use by public and private R&D programs and the solar industry to foster wider interest in commercial plants.

Actual Outcomes:

1. Completed all primary tests and data collection goals, including demonstrating full operational flexibility and successful operation of an advanced receiver panel technology.
2. Specific technical outcomes:
 - Gross turbine output as a function of heat input to the steam generator agreed well with design estimates.
 - The efficiency of the molten salt receiver agreed well with design predictions.
 - The energy storage subsystem fully met efficiency predictions.
 - Between July 1 and July 7, 1998, the plant demonstrated a key advantage of the molten salt central receiver by delivering 24 hour a day continuous solar-electric

power to the grid (153 hours). The project has therefore demonstrated full dispatch capability.

3. Improved the accuracy of economic projections by obtaining actual performance data for use in scaling the design performance prediction model, Solergy.
4. Improved plant cost predictions by documenting refinements in operation and maintenance procedures and expected outcomes in cost and performance, as well as design and operational refinements to be incorporated in the subsystems for commercial plant.
5. SunLab (the solar thermal program collaboration between the National Renewable Energy Laboratory) is documenting the overall project results for use by public and private R&D programs and the solar industry to foster wider interest in commercial plants.

Project Status:

The project has been completed.